

CONTINUATION OF THE HANIAN LOWE PERIOD ASSET EVALUATION

TECHNICAL REPORT NO. 1

VEIA NETWORK EVALUATION AND AUTOMATIC PRODUCTION SYSTEMS

Prepared by
Lynn A. Shoen and Allen C. Skansen

TEXAS INSTRUMENTS INCORPORATED
Equipment Group
Post Office Box 4018
Dallas, Texas 75212

Prepared for

AIR FORCE TECHNICAL APPLICATIONS CENTER
Alexandria, Virginia 22314

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CONTINUATION OF THE IRANIAN LONG PERIOD ARRAY EVALUATION

TECHNICAL REPORT NO. 1

VELA NETWORK EVALUATION AND AUTOMATIC PROCESSING RESEARCH

Prepared by
Lynn A. Shaner and Alan C. Strauss

TEXAS INSTRUMENTS INCORPORATED
Equipment Group
Post Office Box 6015
Dallas, Texas 75222

Prepared for
AIR FORCE TECHNICAL APPLICATIONS CENTER
Alexandria, Virginia 22314

Sponsored by
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In the area of signal analysis, signal-to-noise ratio gains due to beamforming and site-to-site signal similarities are investigated. Using a processed data base of 613 events, regionalized detection capability estimates and earthquake-presumed explosion discrimination are presented. Finally, the report briefly presents a comparison of the array and the closest Seismic Research Observatory station. ←

Conclusions regarding the above areas of investigation and plans for future work necessary to complete the ILPA evaluation are also presented.

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In the area of long-period noise analysis, this report discusses RMS noise levels and trends and average noise RMS amplitude spectra for both the individual sites and the beamformed data. The array noise data is also used to investigate the questions of noise coherence and propagating noise.

In the area of signal analysis, signal-to-noise ratio gains due to beamforming and site-to-site signal similarities are investigated. Using a processed data base of 613 events, regionalized detection capability estimates and earthquake-presumed explosion discrimination are presented. Finally, the report briefly presents a comparison of the array and the closest Seismic Research Observatory station.

Conclusions regarding the above areas of investigation and plans for future work necessary to complete the ILPA evaluation are also presented.

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SECTION I INTRODUCTION

A. DISCUSSION

The Iranian Long-Period Array (ILPA) is located near Teheran, Iran. This array, which became operational on 1 May 1976, is a seismic recording installation comprised of a central recording station and an array of seven remote sites.

This report presents the results of a continuation of the evaluation of this installation. In the preliminary ILPA evaluation (Strauss, 1976), attention was focused on data quality and sources of data errors, beamforming gains in signal-to-noise ratio, first estimates of detection capability, and M_s - m_b relationships. Due to the limited time available between reception of ILPA data and the end of the contract period, no noise analysis was performed. Since no recognized presumed nuclear explosions occurred during May, 1976 (from which time frame the data base was drawn), it was not possible to comment on the ILPA discrimination capability.

In this continuation of the ILPA evaluation, emphasis was placed on improving and refining the work started under the preliminary evaluation. With sufficient data now available, it was also possible to investigate the nature of the noise field at ILPA, regionalize the ILPA detection capability estimates, and consider the ILPA discrimination capability.

B. THE SYSTEM

The instrumentation and operation of the Iranian Long-Period Array have been described in detail in the operation and maintenance manual

for the ILPA seismic system and in the report on the preliminary evaluation of ILPA (Strauss, 1976). Therefore, it is only necessary here to briefly describe the system.

Each remote site of the seven-element array has a three-component broadband seismometer (KS 36000) located in a 100-meter deep bore-hole to reduce wind-generated noise. Each seismometer is a force-balance type which produces an output proportional to earth accelerations over the frequency range 0.02 - 1.0 Hz. The instrumentation at each remote site also includes a data acquisition subsystem, a telemetry subsystem, and a power subsystem. The data recorded at each site are transmitted directly to the central recording station, with one exception. Since site 6 does not have line-of-sight with the central recording station, the data from site 6 are relayed through site 5 to the central recording station. The locations of the remote sites are listed in Table I-1 and shown in Figure I-1.

The central recording station processes and records data received from the seven remote sites. The instrumentation housed in the central recording station includes the station processor, the visual recording system, the magnetic digital tape recording system, and the timing, telemetry, and power systems. The visual recording system converts the digital signals from the remote sites back to analog form for display on drum recorders and develocorders. The digital magnetic tape recording system records three components of long-period motion from each of the seven remote sites. This system is also used for the tasks of providing data for beamforming and display and of editing data to other tapes.

The output of the ILPA data recording system available to this evaluation task is the digital magnetic tape recorded in the satellite tape format. This is a second digital magnetic tape recording system which records three components of long-period motion from each of the remote sites and

TABLE I-1
REMOTE SITE COORDINATES

Site	Location		Distance From Reference Site (km)	
	Latitude (°N)	Longitude (°E)	North	East
1 (ref)	35°24'58.3"	50°41'19.5"	0.0	0.0
2	35°39'46.1"	50°53'51.5"	27.277	19.035
3	35°28'34.0"	51°01'25.5"	6.217	30.377
4	35°14'19.3"	50°54'04.2"	-19.536	19.162
5	35°12'46.2"	50°34'52.0"	-22.415	-9.830
6	35°28'25.2"	50°25'32.2"	5.815	-23.775
7	35°42'10.1"	50°36'32.0"	31.700	-6.951

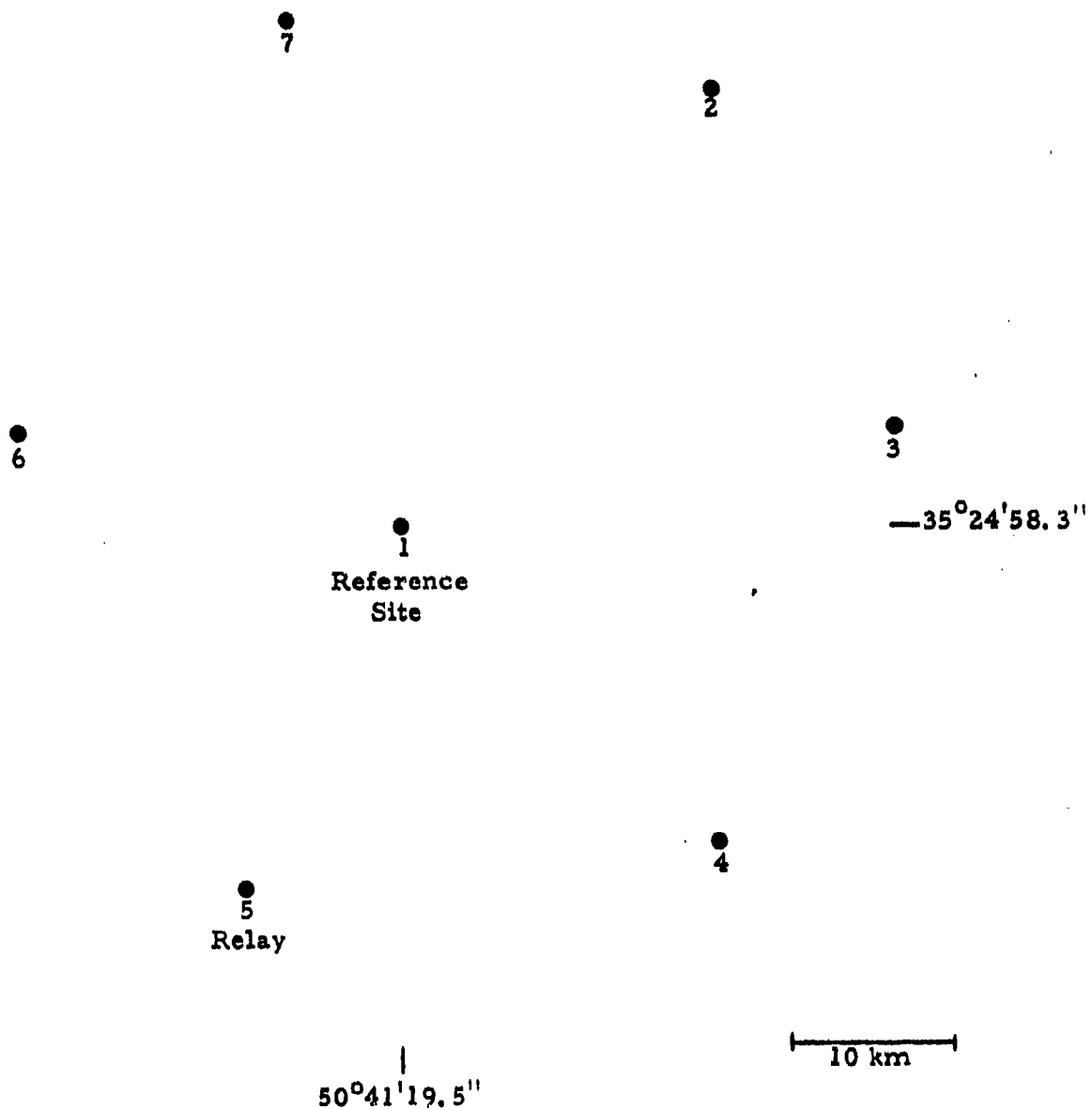


FIGURE I-1
ILPA SITE LOCATIONS

one component of short-period vertical motion (presently, from site 7) continuously. This tape is 800 BPI, 9-track, recorded using two's complement binary arithmetic. The data are quantized at 20.951 computer counts per millimicron ($0.0477 \text{ m}\mu/\text{cc}$) of ground motion for long-period and 16.393 computer counts per millimicron ($0.061 \text{ m}\mu/\text{cc}$) of ground motion for short-period. The data sampling rate is one sample per second of long-period data and twenty samples per second for short-period data.

C. EVALUATION GOALS

The specific goals of this evaluation are:

- To determine data quality, sources of data errors, and reliability for each remote site and for the array as a whole.
- To investigate the long-period noise field characteristics at each remote site and for the array as a whole.
- To investigate the signal-to-noise ratio gains due to beam-forming.
- To investigate site-to-site signal similarity.
- To determine estimates of the array detection capability on a regionalized basis.
- To consider the discrimination capability of the array on a regionalized basis.
- To compare the performance of ILPA with an SRO single-site station located approximately 700 km east of ILPA.

The method of reaching these evaluation goals is as follows. First, a suitable suite of seismic events and noise samples is created from available event lists. The procedure for selecting these events is described in Section II. This section also describes the manner in which the data were

processed and presents some estimates of data quality and array reliability based on data processing experience. The investigation of the local noise field characteristics of the array is presented in Section III. The noise field is characterized by RMS noise level, monthly RMS noise level trends, peak noise amplitudes, and spectral content. The multiplicity of data provided by seven sites also permits investigating the question of propagating noise by means of frequency-wavenumber spectra. Section IV presents estimates of signal-to-noise ratio gains due to beamforming and site-to-site signal similarities. Section V presents estimates of the detection capability of the array in terms of the entire area of interest and in terms of specified sub-regions within this area of interest. In the course of estimating the array detection capability, the effect of mixed events and system malfunctions on these estimates is considered. Section VI discusses the question of discriminating between earthquakes and presumed nuclear explosions. The means of discriminating used in this section is the $M_s - m_b$ relationship. The final major area of this evaluation is found in Section VII, which assesses the performance of the array relative to a nearby single-site station. Section VIII summarizes the findings of this evaluation and suggests future avenues of investigation. Section IX lists the references cited in this report. Finally, Appendix A describes the data base used in this evaluation.

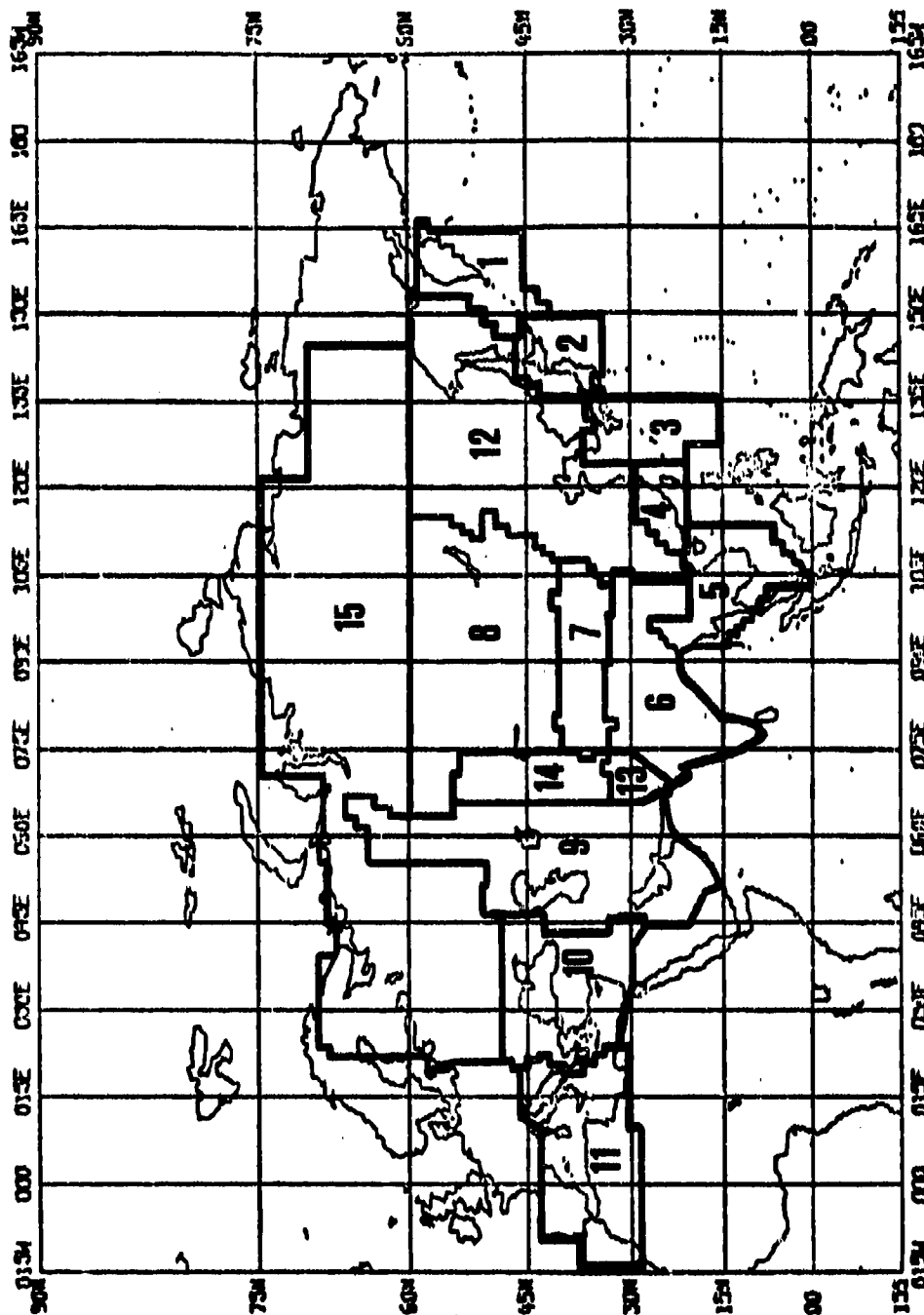
SECTION II

THE DATA BASE

A. FORMATION OF THE DATA BASE

The data base used in this continued evaluation of the Iranian Long-Period Array is essentially a subset of the data base used in the Seismic Research Observatories evaluation (Strauss, 1977). This data base was formed by first selecting all events with Eurasian epicenters as listed by the Norwegian Seismic Array (NORSAR) bulletin. (This was the only available event list at the time the data base was formed.) The time frame selected was from 22 December 1975 to 30 September 1976, when the NORSAR bulletin ceased to be issued. This yielded a list of 2697 events.

This list was far too large to be successfully dealt with and was therefore reduced. First, the events were grouped by seismic regions as defined by Flinn and Engdahl (Flinn and Engdahl, 1965). Those regions containing fewer than 80 events were dropped from the event list. Next, the remaining seismic regions were broken into their geographic sub-regions, again as defined by Flinn and Engdahl. Those sub-regions which contained only a few events and which were separated from the main body of event-containing sub-regions in the region were then rejected and their contained events deleted from the event list. The remaining regions (shown in Figure II-1) were used in this evaluation. The regions have been renumbered but have the same boundaries as those of Flinn and Engdahl, with the exception of their region 19, which was sub-divided to form regions 1 and 2 of Figure II-1. The subregions composing each region are listed in Table II-1.



MILLER MODIFIED MERCATOR PROJECTION
MAP SCALE: 0.03429 INCHES/DEGREE LONGITUDE

FIGURE II-1
REGION BOUNDARIES

TABLE II-1
DATA BASE REGIONALIZATION

Region # As Used in This Report	Flinn & Engdahl's Region #	General Area	Flinn & Engdahl's Geographic Subregions
1	19	Kuriles-Kamchatka	217, 218, 219, 221, 222, 225
2	19	N. Japan	224, 227, 228, 229, 230
3	20	S. Japan	232, 233, 234, 235, 237, 238
4	21	S. E. China	242, 243, 244, 245, 246, 247
5	25	Burma	294, 296, 297, 298
6	26	N. India	302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 313, 315, 317, 318, 319
7	27	Tibet	320, 321, 322, 323, 324, 325
8	28	Central Asia	326, 327, 328, 329, 330, 331, 332, 334
9	29	Iran-Ural Mountains	335, 336, 337, 338, 339, 340, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 353, 354
10	30	Greece-Turkey	357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 368, 369, 370, 371, 373, 375
11	31	W. Mediterranean	381, 382, 383, 390, 391, 392, 398, 399, 400
12	41	E. China	657, 658, 660, 661, 662, 663, 664, 665, 666
13	47	S. Pakistan	709, 710, 711, 712
14	48	N. Pakistan-Afghanistan	713, 714, 715, 716, 717, 718, 719, 720
15	49	N. Russia-Siberia	724, 726

At this point, the data base contained approximately 2300 events. To bring this down to a manageable size, events were systematically deleted (every other event, two out of every three events, as needed) from those regions containing more than 120 events until they each contained approximately 120 events. This reduced the data base to 1472 events.

The ILPA data base was created from this data base by selecting all events for which the array was nominally operational. This resulted in a data base of 497 events occurring between 1 May 1976 and 30 September 1976. Finally, this data base was increased to 613 events by selecting events from the above-defined regions as listed by the National Earthquake Information Service (NEIS) event bulletin from 1 October to 20 December 1976. The event parameters of this data base are presented in Appendix A.

In the preliminary ILPA evaluation, the data base consisted of 281 events from May 1976. For the current data base, these events were subjected to the same regionalizing procedure as the new events, reducing the total for May 1976 from 281 to 213. The 67 events of the old data base which were not included in the new data base were rejected because their epicenters were not in regions used in this evaluation. These 67 events will be used in the discussion of data quality and array reliability however, since these matters are independent of region.

Formation of the noise data base will be discussed in detail in the section on noise analysis (Section III). In brief, the noise data base was formed by searching the NORSAR and NEIS event bulletins for daily time intervals of at least one hour in duration during which no seismic signals would be expected to arrive at the array. Noise edits were then created by selecting data segments 4096 seconds in length sampled at a rate of one sample per two seconds from these intervals.

B. DATA PROCESSING METHOD

The computer processing of seismic signals and noise samples can be divided into two functional stages - the basic processing stage and the analysis processing stage.

The basic processing stage is outlined in Figure II-2. The desired time segments of signal or noise are first edited from the merge tapes created by Teledyne/Geotech. (These merge tapes each contain three consecutive days of ILPA data recorded at 1600 BPL.) The output from the edit program consists of trace mean information for each component of each site, quality control information, and a permanent hold tape of the edited data. The quality control information consists of messages indicating the presence of parity errors, timing errors, clipped data, and spiked data. Also printed out is a summary of segment powers, which can be used to determine bad sites. (Bad sites are those sites which are dead, contain uncorrectable spikes, or display abnormally high or low power levels.) At this point, the analyst uses the quality control information to guide him in selecting the array sites to be input to the beamforming program.

The next major program of the basic processing stage performs trace mean removal, rotation of the data from their recorded vertical, north, east (V, N, E) configuration to a vertical, transverse, radial (V, T, R) configuration, and beamforming of the good sites. Rotation of the data separates the surface waves recorded on the horizontal components, theoretically resulting in two components of Rayleigh-wave motion (V and R) and one component of Love-wave motion (T). Noise samples retain their V, N, E configuration. Both the edit and beamforming programs operate on one 128-point data segment at a time, continuing until the desired data length has been processed.

The beamforming program operates by computing arrival time delays at each site relative to a reference site (site 1) using fixed velocities of 4.0 km/sec for Love waves and 3.5 km/sec for Rayleigh waves.

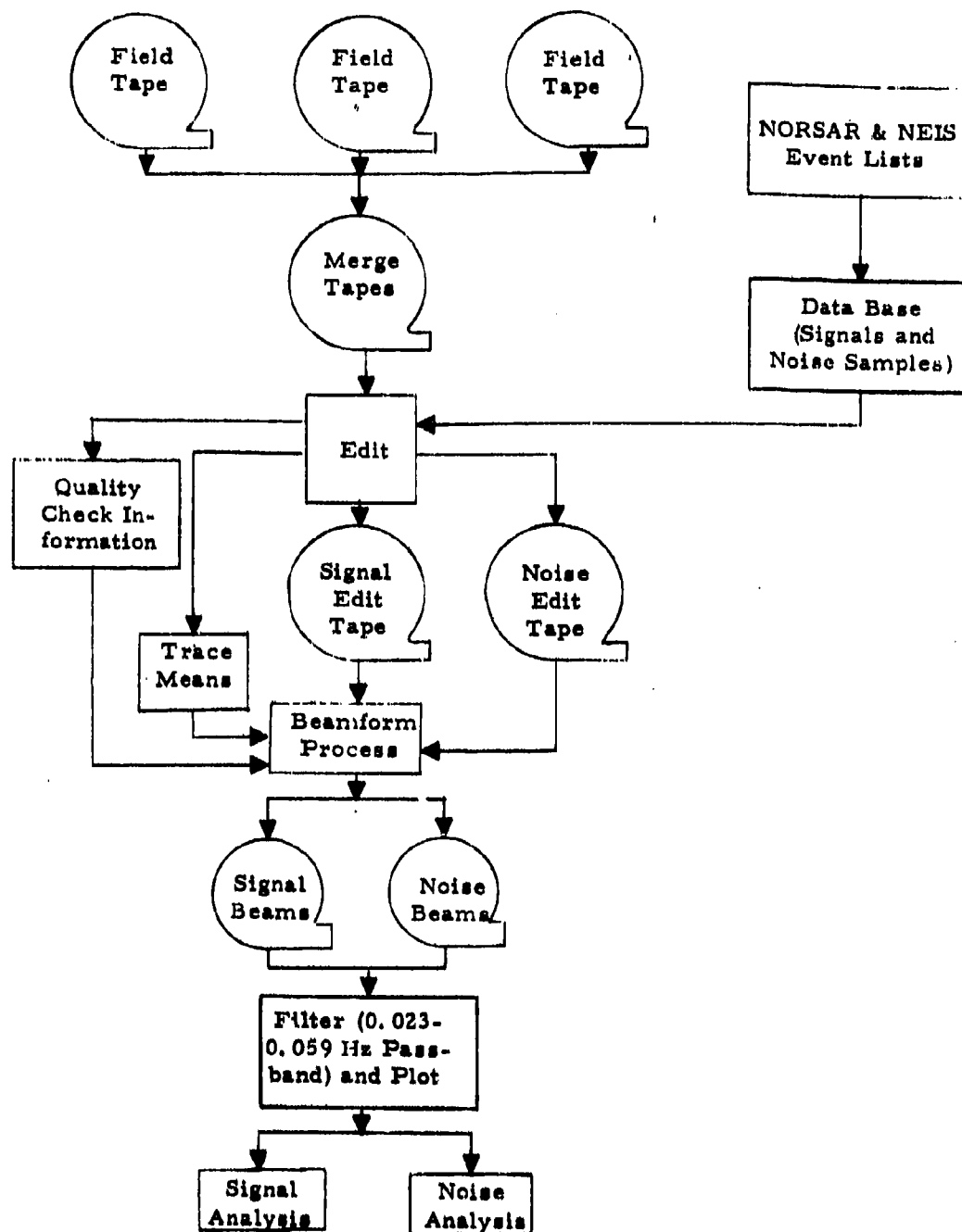


FIGURE II-2
DATA PROCESSING METHOD

The data from each site are then time-aligned using these time delays, summed, and scaled. This process produces a signal-to-noise ratio improvement by suppressing random noise by a factor approximately equal to the square root of the number of sites used. This program outputs three components of motion from a reference site (usually site 1) and three beams (V, T, R) to a permanent hold tape with appropriate annotation.

The final program of the basic processing stage performs bandpass filtering (0.023 - 0.059 Hz passband) of the reference site and beam traces and outputs plots suitable for analysis.

The various programs used in the analysis processing stage will be described in the sections on noise analysis and signal analysis.

C. ARRAY RELIABILITY

The first point to be considered in any assessment of array reliability is the percentage of time for which the array is nominally operational. Table II-2 shows that this factor varies greatly from month to month. (These percentages represent the percentage of each month for which data was received at the Seismic Data Analysis Center in Alexandria, Virginia.) In the first thirteen months of operation, ILPA suffered from three major problems. Between 22 June 1976 and 6 August 1976, the array was down due to a malfunction of the air conditioner compressor, which allowed temperatures to rise above the operational limits of the CRS hardware. The second down period, from 18 September to 1 November 1976, was due to problems with the satellite-format tape recorders. (From the authors' point of view, the array is down when no data is available at the Seismic Data Analysis Center in Alexandria, Virginia, regardless of whether the remainder of the sensor - transmitter - recorder system comprising the array is operational. Thus, the array is considered to be down when the

TABLE II-2
PERCENTAGE OF TIME ILPA IS OPERATIONAL

May	1976	100%
June	1976	77%
July	1976	3%
Aug.	1976	87%
Sept.	1976	50%
Oct.	1976	0%
Nov.	1976	100%
Dec.	1976	68%
Jan.	1977	0%
Feb.	1977	79%
Mar.	1977	87%
Apr.	1977	100%
May	1977	81%
		<hr/>
		Average = 64%

satellite-format tape recorders are down.) The third down period, from 20 December 1976 to 2 February 1977, was due to problems with the thermal electric generators and the satellite-format tape recorders.

Overall, in the thirteen month period shown in Table II-2, the average up time percentage was only 64%. However, as hardware problems of the types described above are found and corrected, one can expect this value to increase. An indication that this is the case may be found in Table II-2, where the average up time for the last four months is 87%.

Even when the array functions as designed and tapes in the satellite format are received at the Seismic Data Analysis Center, two factors may prevent the analyst from processing a desired time frame. First, no data is recorded during the interval between the time one tape is filled and the next is mounted on the tape drive. (The average time gap between tapes is ten minutes.) Second, a tape is occasionally received which is unreadable due to such factors as poor tape quality or dust and dirt on the tape. When either of these occurs, the analyst cannot examine the time frame in which he is interested.

Out of 680 events examined (613 of the current data base plus 67 additional events from the data base of last year), 87 could not be processed due to gaps in the recorded data or unreadable data. Thus, it appears that even if the array is nominally operational 100 percent of the time, the analyst can expect to be unable to process approximately 12 percent of the data. However, it should be noted that 45 of the 87 events not processed were lost to unreadable tapes, a problem which should not be too difficult to rectify. Correction of this problem would bring the loss rate down to approximately 6 percent.

Even after an event has been successfully processed, system malfunctions can prevent the analyst from determining whether the data shows

the desired signal, seismic noise, or a mixed event. These system malfunctions take the form of spikes, glitches, and data drop-outs. These system malfunctions degraded 28 of the 680 events examined last year and this year for a loss rate of 4 percent.

The overall ILPA reliability estimate is determined from the above causes of loss of data. This estimate is expressed as:

$$\text{Reliability} = \text{Probability (array is operational)} * \text{Probability (data is recorded and readable)} * \text{Probability (no malfunctions)}.$$

The worst-case reliability assumes no improvements in the up-time or quality of data recording. This estimate is:

$$\text{Reliability} = (0.64) * (0.88) * (0.96) = 0.54.$$

If one assumes the improvement in operational reliability suggested by the last four months shown in Table II-2 is permanent, the array reliability becomes:

$$\text{Reliability} = (0.87) * (0.88) * (0.96) = 0.73.$$

Finally, there is no reason why all recorded data should not be readable. If proper tape handling procedures in recording and shipment are observed, the array reliability can be estimated as:

$$\text{Reliability} = (0.87) * (0.94) * (0.96) = 0.79.$$

This is the best-case estimate.

D. SITE REJECTION STATISTICS

Another indication of the performance quality of ILPA is the number of sites considered to be acceptable for inclusion in beamforming. A site is rejected from the beamforming process if any of the following occurs on one or more site components:

- The component is dead
- The data contain uncorrectable spikes or clipped data
- The data contain power surges raising the 128-point processing segment powers more than ten times the power of the preceding and following segments
- The data contain 128-point processing segments with zero power (data drop-outs)
- The data contain 128-point processing segment powers consistently higher than the segment powers of corresponding components at other sites.

The decision as to whether to accept or reject a site is made using the edit printout, which lists segment powers for each component of each site of the array.

Of the 680 events in the combined data bases of last year and this year, unreadable or missing data prevented the processing of 87 events. The number of times each site was rejected from beamforming for the 593 processed events is summarized in Table II-3. (Note that site 1 did not become operational until 5 May 1976 and site 3 did not become operational until 8 September 1976.) The data of Table II-3 show that site 6 had the highest rejection rate. In almost all cases, the reason for rejecting this site was transmission errors occurring during the relaying of data from site 6 through site 5 to the central recording station. These transmission errors were fairly uniformly distributed throughout the time period covered by the data base. The transmission errors manifested themselves in the data as power surges, spikes, and data drop-outs.

Table II-4 presents the reasons for rejection of each site. Single segment power surges and entire component power surges are presented jointly as 'POWER SURGES'. The heading 'DEAD COMPONENT'

TABLE II-3
SUMMARY OF SITE REJECTION STATISTICS

Site	Total Number of Times Site was Available	Number of Times Site was Rejected	Percent Re- jected (%)
1	573	65	11.3
2	593	79	13.3
3	129	21	16.3
4	593	170	28.7
5	593	108	18.2
6	593	234	39.5
7	593	60	10.1

TABLE II-4
REASON FOR SITE DELETION

Reason \ Site	Percentage of Total Number of Rejections						
	1	2	3	4	5	6	7
Power Surge	76%	36%	50%	94%	34%	49%	36%
Dead Component	11%	57%	50%	5%	61%	39%	49%
Spikes/Clipped Data	13%	7%	0%	1%	5%	12%	15%

includes data drop-outs and dead components. Following site 6, site 4 had the highest rejection rate. Table II-4 indicates that the primary reason for rejecting this site was power surges. Sites 3 and 5 had the next highest rejection rates. For these sites, power surges and dead components caused about the same number of rejections. Sites 1, 2, and 7 had the lowest rejection rates. Power surges accounted for the majority of rejections of site 1. At sites 2 and 7, dead components accounted for slightly more rejections than did power surges. In all cases, spikes and clipped data accounted for only a small number of site rejections.

E. PROBABILITY OF MIXED EVENTS

The manner in which the data base for the evaluation of the Iranian Long Period Array was selected produces a data base which is essentially a random sampling of Eurasian seismic events. Since no effort was made to exclude obviously mixed events, the mixed event statistics derived from analysis of this data base should accurately reflect the frequency of occurrence of mixed events. (A mixed event is any event whose waveforms are masked or interfered with by the waveforms of a second event.)

Table II-5 presents the mixed event statistics and derived probability of mixing for four bodywave magnitude (m_b) ranges. These values are compiled for ranges in m_b rather than for individual m_b values to provide more robust statistics. (It seems reasonable to assume that there will be no major changes in the probability of mixing from one m_b value to the next.) This table indicates that, as one might expect, the probability of mixing very gradually drops as the bodywave magnitude increases. This gradual decrease in the probability of mixing is due to beamforming the data, which suppresses off-azimuth signals so that events which are mixed on the reference site can sometimes be detected on the beam data.

TABLE II-5
ILPA BEAM DATA MIXED EVENT STATISTICS

m_b Range	Number of Mixed Events	Number of Non-Mixed Events	Probability of Mixed Event
3.1-3.5	27	63	0.30
3.6-4.0	52	114	0.31
4.1-4.5	20	85	0.19
4.6-5.0	12	66	0.15

SECTION III

NOISE ANALYSIS

A. DISCUSSION

The goal of this section is to determine the long-period noise field characteristics of the Iranian Long Period Array. Both single-site and beamformed data will be examined in order to estimate the effects of the beamforming process on the noise field. The major effort will be concentrated on the noise in the 0.023-0.059 Hz signal window. This window is used in the noise analysis to permit one to consider the effect of noise level on detection capability. Some information on the noise field at frequencies outside this window is presented by average noise amplitude spectra.

The analysis of the noise field is divided into two parts termed the basic noise analysis and the extended noise analysis. The basic noise analysis covers the points common to the analysis of the noise field at a single-site station such as one of the Seismic Research Observatories. These points are RMS noise amplitudes, RMS noise trends, spectral content of the noise, and peak noise amplitudes. The extended noise analysis covers those points which can only be investigated with array data. These points are multichannel noise coherence and propagating noise.

The noise sample data base was formed by searching the NORSAR event lists for daily time intervals of at least one hour in duration during which no seismic signals would be expected to arrive at the array. Data segments 4096 seconds in length were then selected from these intervals and processed as described in Section II. After processing, the data were plotted and visually examined for unreported signals and system malfunctions. If either of these was found, the noise sample was rejected unless the signal

or malfunction occurred near the start or end of the sample. In this case, 2048 seconds of the noise sample were used.

The definition of seismic noise used in this report is most clearly stated by Enders A. Robinson (Robinson, 1967):

"Any ground motion that is not caused by an explosion or an earthquake is usually regarded as ambient seismic noise. The predominant components of such seismic noise are surface-generated microseisms that originate from meteorological, hydrodynamic, or cultural sources. Such microseisms chiefly propagate along the surface of the earth as Rayleigh waves."

B. BASIC NOISE ANALYSIS

The goals of the basic noise analysis were to estimate the long-period RMS noise levels, the peak 25-second noise amplitudes, and the spectral content of the noise for each of the three components of motion (vertical, north, and east) as recorded at each array site and for the beamformed noise sample. The overall evaluation time frame was from 1 May 1976 to 29 April 1977. This was used to study the reference site and beam noise. Thirty days of noise data were selected from within this time frame to study the noise at the individual sites.

After the preliminary processing and visual inspection, the noise samples were input to a program which performs the following functions:

- Compute RMS noise values uncorrected for instrument response in the 0.023-0.059 Hz passband.
- Measure zero-to-peak 25-second noise amplitudes.
- Compute the power spectrum for each component of motion of the noise sample and smooth to 128 frequencies.
- Compute RMS noise values corrected for instrument response in the 0.023-0.059 Hz passband.

The program output all measured and computed values on punched cards to facilitate data input to succeeding plot programs. The 25-second noise amplitudes were measured as the maximum 25-second noise amplitude of each component of motion of the noise sample.

The mean long-period RMS noise values in millimicrons as measured in the 0.023 - 0.059 Hz passband are presented in Table III-1. These values are uncorrected for instrument response. The individual RMS values were not plotted due to the relatively small number of samples used. In every case except one (site 1 north) the vertical component displays somewhat lower mean RMS noise values than do the horizontal components. There appears to be no correlation between the mean noise levels at the sites and the potential cultural noise sources described in the final report on the installation of ILPA (Texas Instruments, 1977). For example, an active manganese mine is described as being located 3 km from site 3, which has mean RMS noise values at about the median for the seven sites. It would appear that if the types of cultural activity in the area of the array produce long-period transient noise trains, these noise trains do not materially affect the mean RMS noise levels.

The long-period RMS noise values in millimicrons for the vertical, north, and east components of motion are plotted versus Julian day for the reference site (site 1) in Figure III-1 and for the beam in Figure III-2. In these figures, RMS noise values for consecutive days are connected by solid lines. Gaps of one or two days in length are due to bad noise samples. The three large gaps are due to array system failures, the causes of which were discussed in Section II. The monthly RMS noise level trends which were derived from these RMS noise values are shown in Figure III-3 for the reference site data and Figure III-4 for the beam data. Due to array down time, it is difficult to determine how the noise level varies with time. It appears that the noise levels rise in the winter months and decrease with

TABLE III-1
ILPA INDIVIDUAL SITE
AVERAGE RMS NOISE AMPLITUDES IN $m\mu$
(UNCORRECTED FOR INSTRUMENT RESPONSE)

Site Number	V		N		E		No. of Samples
	Mean	S. D. *	Mean	S. D. *	Mean	S. D. *	
1	9.13	2.32	8.76	1.98	10.03	2.92	30
2	7.40	1.80	12.75	6.17	10.98	4.20	18
3	8.08	3.59	9.68	3.16	9.47	3.60	7
4	7.43	1.44	13.20	8.83	12.97	8.69	14
5	6.53	1.42	8.33	1.42	9.54	2.52	24
6	7.97	2.73	9.00	2.29	10.17	3.63	15
7	8.45	2.32	9.32	2.42	13.56	5.20	32

* Standard Deviation

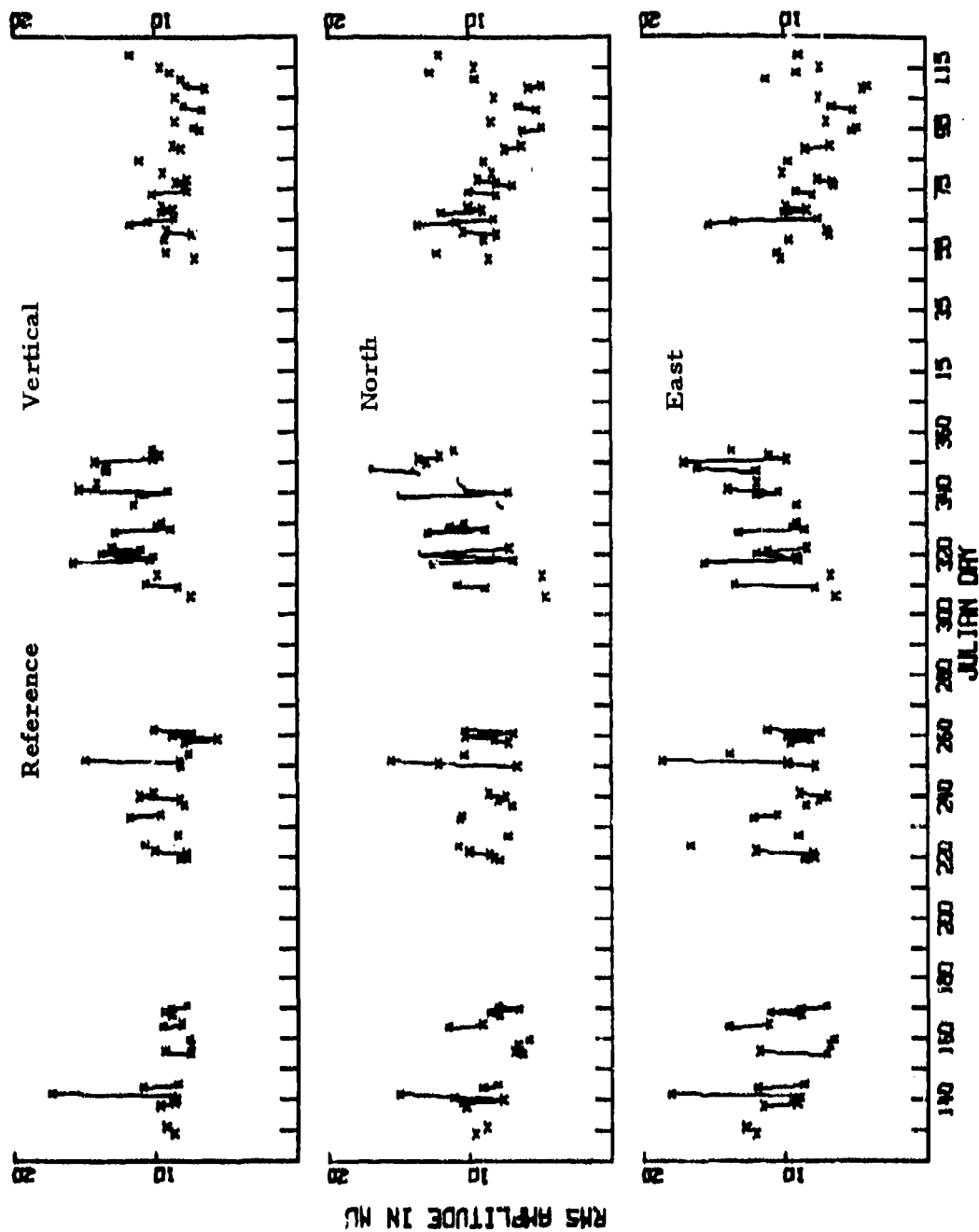


FIGURE III-1
REFERENCE SITE (SITE I) RMS NOISE IN MILLIMICRONS

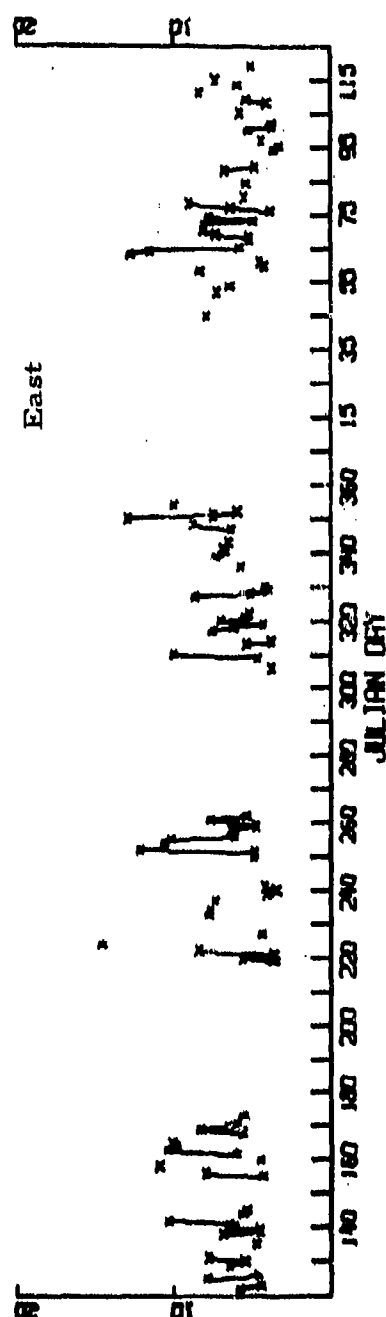
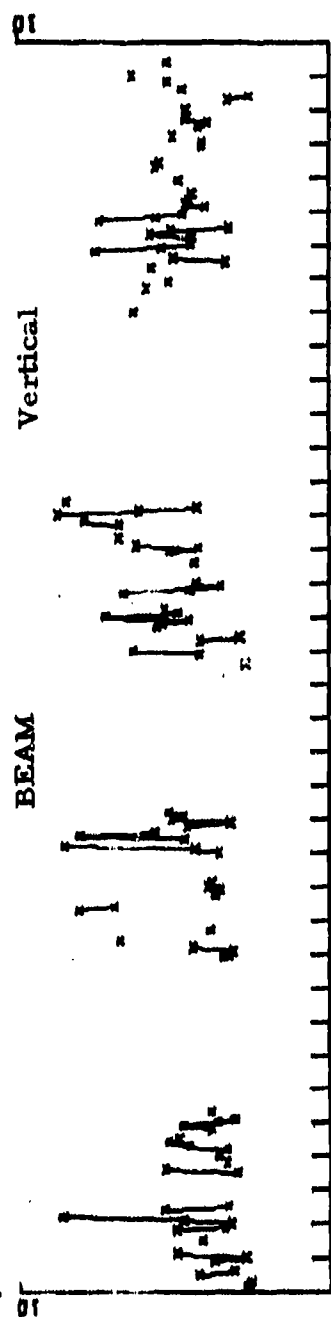


FIGURE III-2
BEAM RMS NOISE IN MILLIMICRONS

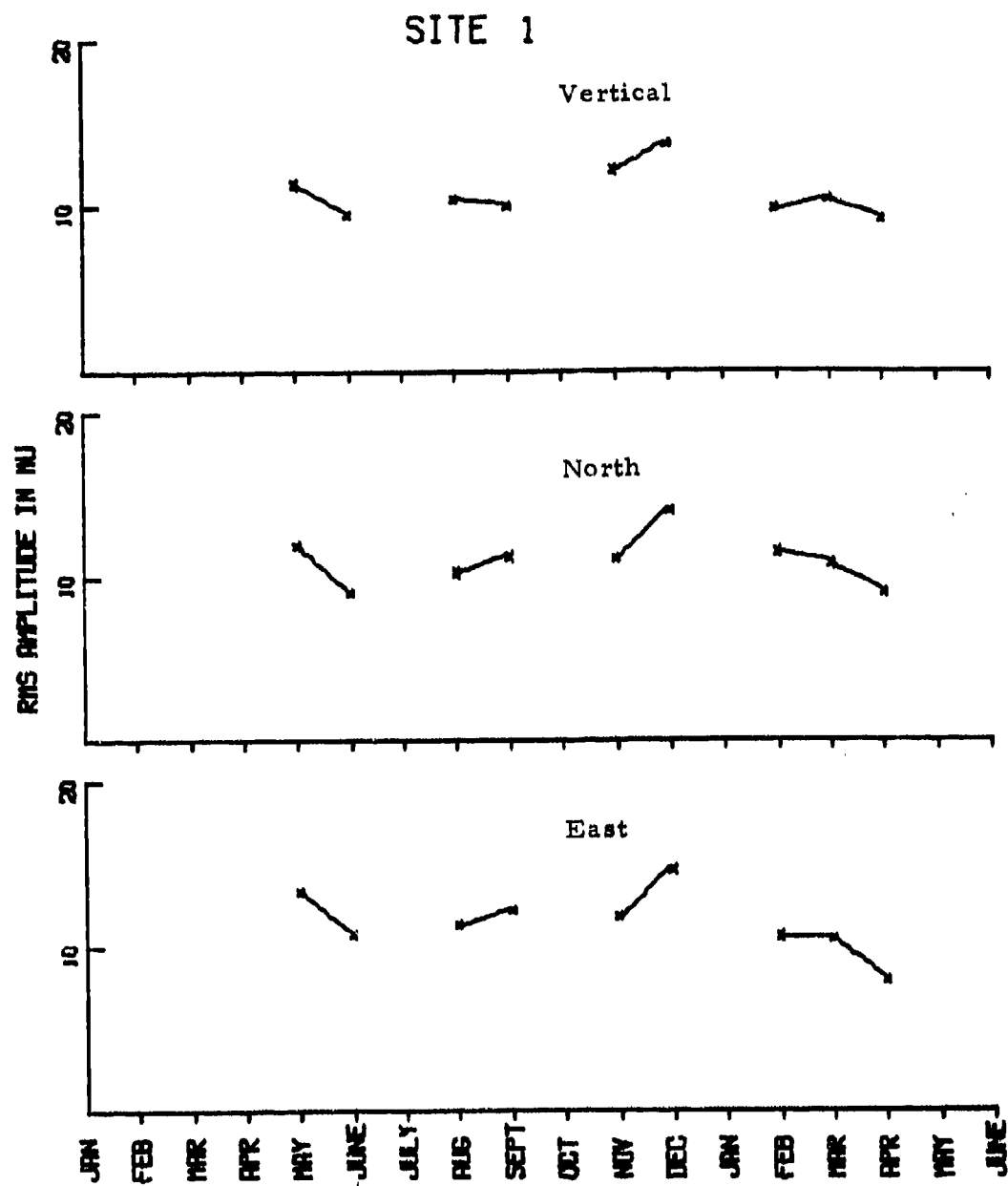


FIGURE III-3
REFERENCE SITE (SITE 1) RMS NOISE LEVEL TRENDS

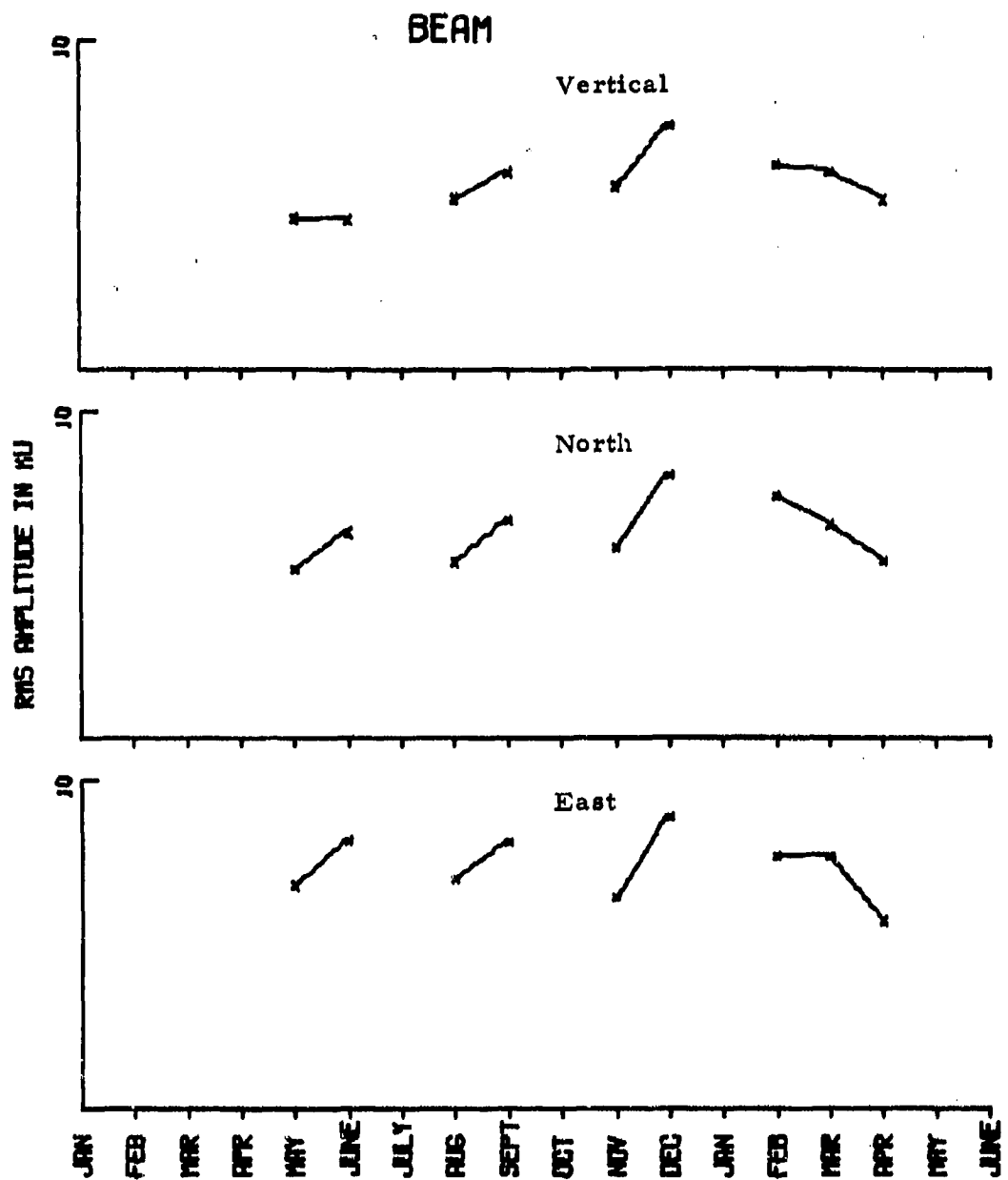


FIGURE III-4
BEAM RMS NOISE LEVEL TRENDS

the onset of spring. The only significant difference between the reference site data and beam data as portrayed by Figures III-1 to III-4 is the absolute noise level. Table III-2 compares the overall reference site and beam mean RMS noise levels. This table shows that beamforming reduces the RMS noise level in the 0.023 - 0.059 Hz passband by approximately 6.1 dB on the vertical component, 4.8 dB on the north component, and 3.6 dB on the east component.

Table III-3 presents the statistics for the 25-second noise amplitudes measured on each noise sample. The values used to compute these statistics were the largest 25-second noise amplitudes of each noise sample measured from zero-to-peak in millimicrons. The means and standard deviations in this table are for the base ten logarithms of these amplitudes. These values present another measure of noise suppression due to beamforming. The peak 25-second noise amplitudes are reduced by approximately 5.6 dB on the vertical component, 5.2 dB on the north component, and 5.0 dB on the east component due to beamforming. These values compare fairly well with the equivalent values for RMS noise suppression on the vertical and north components. The lower RMS noise suppression for the east component (3.6 dB) suggests that some range of frequencies on the east component in the 0.023 - 0.059 Hz passband contains noise energy which is to some extent correlated from site to site and which therefore is not as well suppressed by beamforming as noise at other frequencies.

Figure III-5 shows average RMS noise amplitude spectra for each of the remote sites of the array and for the beamformed noise data. These spectra are uncorrected for instrument response. They were computed by averaging the spectra measured from each noise sample and converting these average spectra to RMS amplitudes using Parseval's formula

$$\text{RMS}_a^b = \sqrt{\Delta f \sum_{i=a}^b |A(f_i)|^2 * C(f_i)^2}$$

TABLE III-2
COMPARISON OF SINGLE-SITE AND BEAM RMS NOISE AMPLITUDES
(UNCORRECTED FOR INSTRUMENT RESPONSE)
(ALL VALUES ARE IN MILLIMICRONS)

Type	V		N		E		No. of Samples
	Mean	S. D. *	Mean	S. D. *	Mean	S. D. *	
Ref. Site	9.58	2.19	9.34	2.56	9.86	2.98	97
Beam	4.77	1.44	5.36	1.82	6.51	2.31	113

* Standard Deviation

TABLE III-3
MAXIMUM 25-SECOND NOISE AMPLITUDES
 $\text{LOG}_{10} \left[\frac{\text{ZERO-PEAK*}}{\text{AMPLITUDE}} \right]$

		Mean	Standard Deviation
Reference Site	V	1.44	0.13
	N	1.45	0.14
	E	1.48	0.15
Beam	V	1.16	0.15
	N	1.19	0.14
	E	1.23	0.15

Suppression of 25-Second Noise Amplitudes by Beamforming:

V: 5.60 dB N: 5.20 dB E: 5.00 dB

* Zero-to-Peak amplitudes were measured in millimicrons.

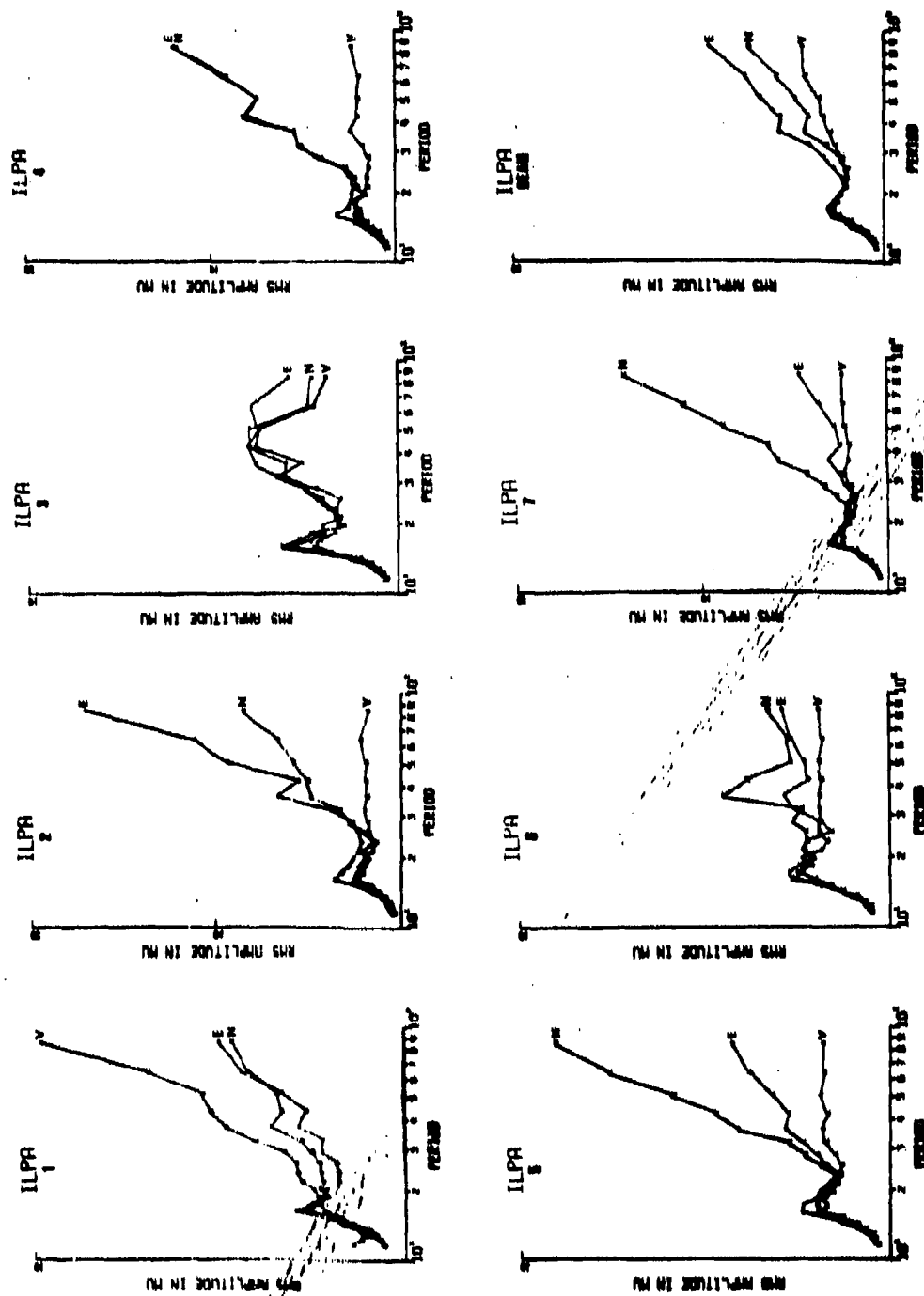


FIGURE III-5
AVERAGE RMS NOISE AMPLITUDE SPECTRA
INDIVIDUAL SITES AND BEAM

where Δf = the elemental frequency interval ($\Delta f = 0.001953$ Hz),
 $|A(f_i)|^2$ = the discrete Fourier transform spectral density estimate at frequency f_i ,
 $C(f_i)$ = the instrument response correction at frequency f_i ,
 a = the initial frequency index, and
 b = the final frequency index.

Since the RMS amplitude at each discrete frequency was desired, in this case $a = b$. Also, since no instrument response corrections were made, $C(f_i) = 1$ for all frequencies.

For all sites except site 1, the RMS noise amplitudes for periods greater than 25 seconds are higher on the horizontal components than on the vertical component. If the noise on the horizontal components at these periods contains a relatively large amount of coherent energy in comparison to the vertical, the difference between the reduction in noise due to beamforming for the vertical and horizontal components will be explained.

Figures III-6 and III-7 show the average RMS amplitude spectra of all noise samples for the reference site and beam data respectively. No instrument response corrections were applied to these data. The left-hand side of each figure shows the average RMS amplitude spectra for the three components of motion. The right-hand side of each figure shows the log RMS amplitude spectra. The vertical bars on these spectra represent plus-or-minus one standard deviation of the noise. These bars represent the day-to-day variability of the noise at each period. The following points should be noted from these figures:

- The smallest decreases in the amplitude spectra due to beamforming occur at the shorter periods. The most noticeable effect of beamforming at periods less than 25 seconds is to make the vertical and horizontal spectra nearly identical.

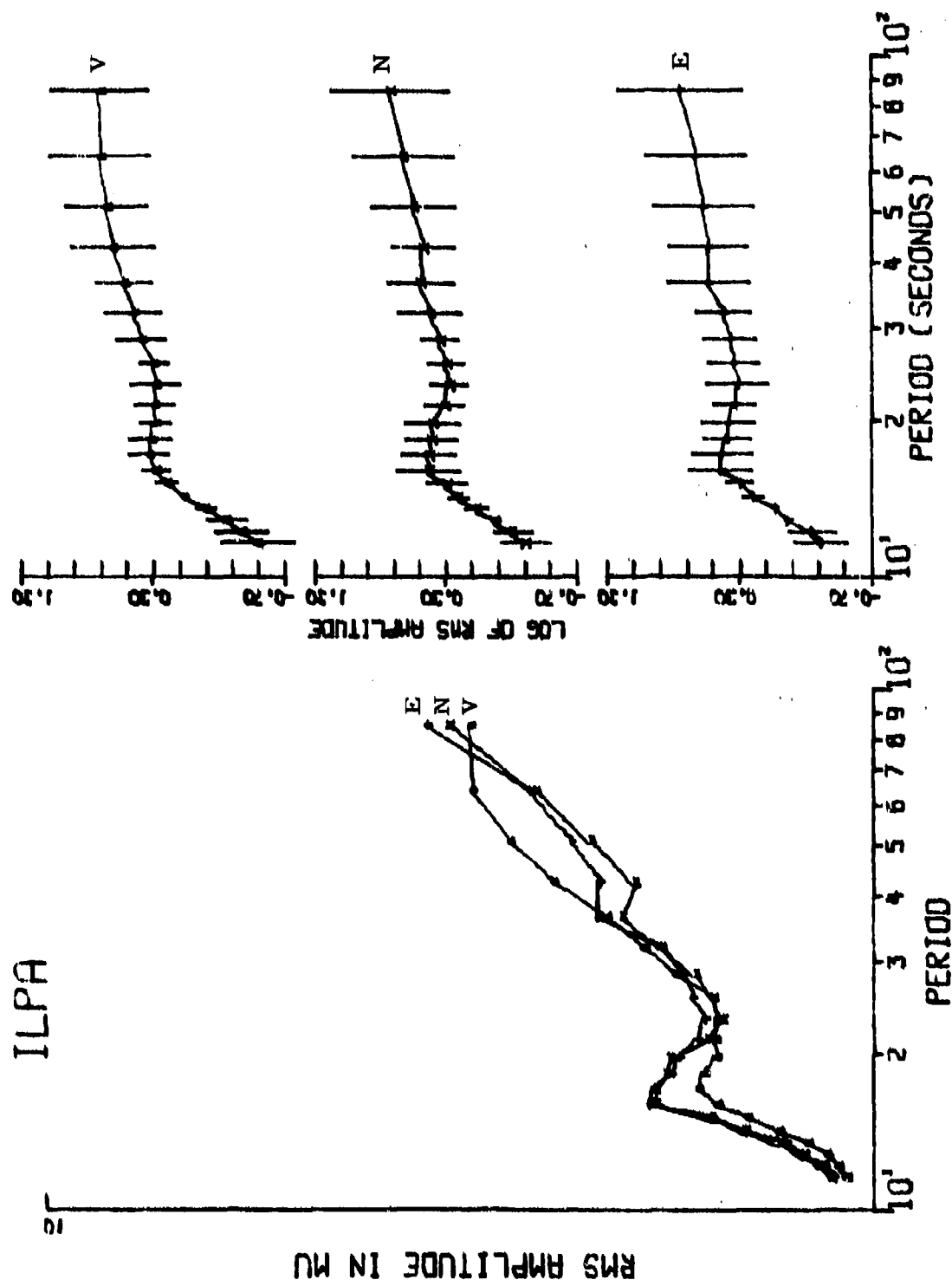


FIGURE III-6

AVERAGE RMS NOISE AMPLITUDE SPECTRA - REFERENCE (SITE 1) SITE
NO INSTRUMENT-RESPONSE CORRECTIONS APPLIED

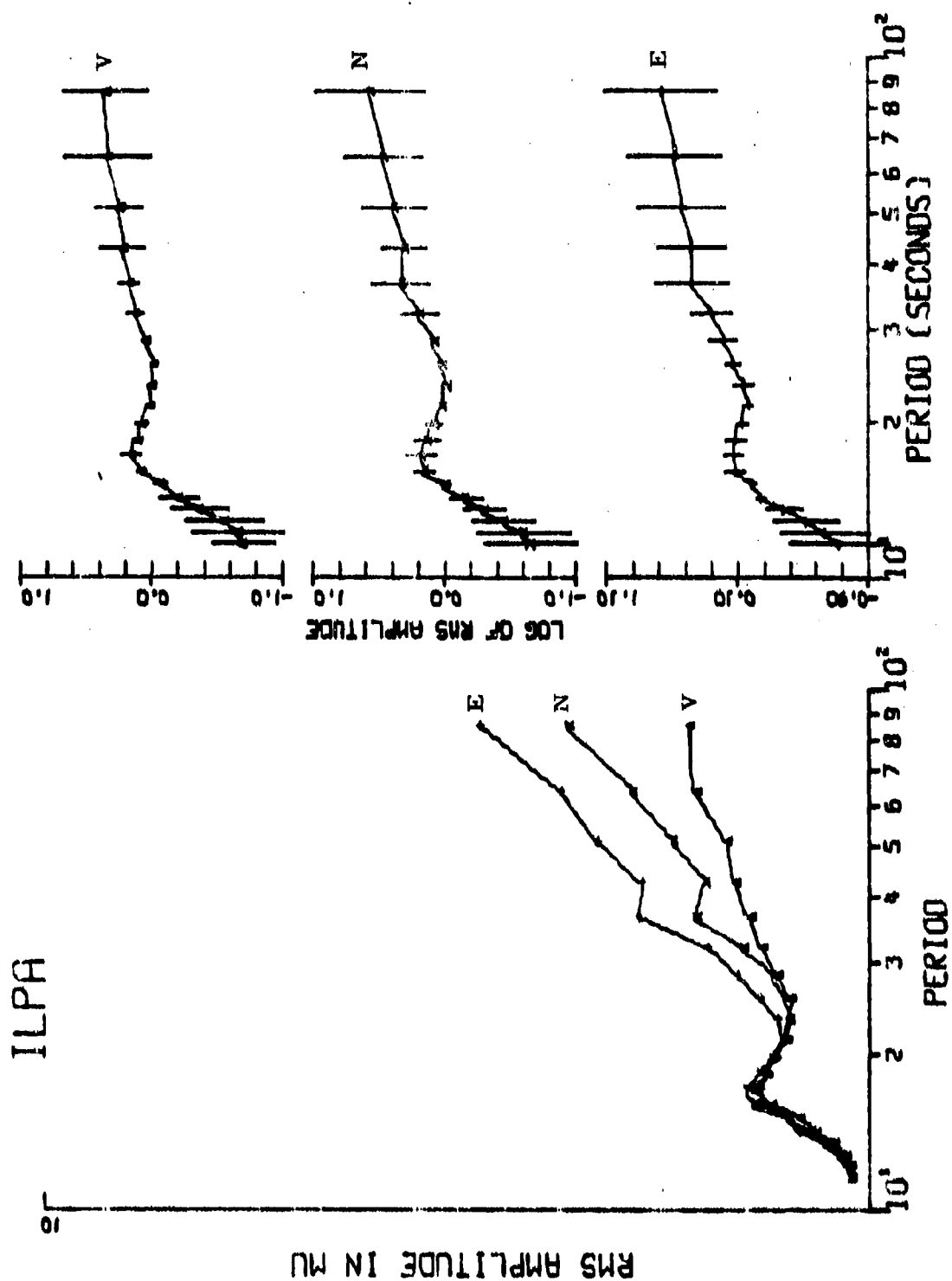


FIGURE III-7

AVERAGE RMS NOISE AMPLITUDE SPECTRA - BEAM
NO INSTRUMENT-RESPONSE CORRECTIONS APPLIED

- At periods greater than 25 seconds, beamforming lowers the vertical-component spectrum much more than the horizontal spectra. The east-component spectrum shows relatively little change due to beamforming.
- The reference site shows greatest day-to-day variation in the noise at periods greater than approximately 28 seconds.
- Beamforming greatly decreases the day-to-day variation in the noise at periods between 14 and 28 seconds.
- Beamforming has very little effect on the day-to-day variation in the noise at periods greater than 28 seconds.

A general conclusion which may be drawn from the preceding observations is that the signal-to-noise ratio may be greatly enhanced by changing the bandpass filter limits from 0.023 - 0.059 Hz (16.9 - 43.5 seconds period) to 0.033 - 0.050 Hz (20 - 30 seconds period). This will sharply curtail the effects of the noise at the microseismic peak and at periods beyond 30 seconds on the signal-to-noise ratio. Since the majority of the signal energy lies within the 0.033 - 0.050 Hz passband, the signal should not be materially affected by this change in filter limits.

C. EXTENDED NOISE ANALYSIS

This subsection deals with the types of noise analysis which can only be performed with array data, i. e., coherence of the noise and directionality of the noise.

Two main programs were used to carry out this phase of the noise analysis. The first program computes crosspower spectral matrices from the time-domain noise data. This is performed in the following manner. The edited data in its recorded vertical, north, east configuration

is entered into the program one 128-point (256 second) segment at a time. The program then removes the trace mean calculated in the edit program from the data segment and Fourier transforms the data segment. To provide greater frequency-to-frequency stability, a three-point Hanning function is applied to the transformed data. This Hanning function may be expressed as

$$T'_i(f) = +\frac{1}{4}T_{i-1}(f) + \frac{1}{2}T_i(f) + \frac{1}{4}T_{i+1}(f)$$

where $T_i(f)$ is the input transformed data at frequency f

$T'_i(f)$ is the output transformed data at frequency f

i = frequency index.

At this point, the crosspower spectral matrices are computed. One matrix is computed for each frequency within the specified passband for each component and site. The program calculates these crosspower spectral matrices $[\Phi]$ for the desired sites i, j from the complex transformed data \bar{X} at each frequency f . Looping on the number of transformed segments (NSEG) stacks the matrix over the entire data trace. In equation form

$$\Phi_{ij}(f) = \sum_{n=1}^{NSEG} \bar{X}_{in} X_{jn}^*$$

Each element of the matrix is scaled to account for the number of transform segments over which the matrix was accumulated and to convert from computer counts to millimicrons. The scale factor is:

$$SCALE = \frac{2\Delta t}{(NPTS)(NSEG)(Q)}$$

where:

Δt = the sampling interval

NPTS = the number of points in each segment

NSEG = the number of segments used, and

Q = the quantization in computer counts per millimicron.

Finally, the scaled crosspower spectral matrices are written on magnetic tape.

The second main program is used to analyze the array noise data by interrogating the crosspower spectral matrices. The analysis options provided by this program are: site power spectra, component average power spectra, multichannel coherencies, and conventional or high-resolution frequency-wavenumber spectra. The two options used in this evaluation are the multichannel coherence and high-resolution frequency-wavenumber spectra.

The multichannel coherence is calculated as follows. The elements of the crosspower spectral matrix corresponding to the reference site crosspowers with each site i to be used in the coherence calculation are placed in an array PHI dimensioned (2, 40). The real portion of the crosspower is in row 1 and the imaginary portion is in row 2. In the case where coherence is to be calculated between the reference site and some other data site, the reference site autopower is placed in a scalar PHI11 and the data site autopower in scalar PHI22. The coherence squared is then calculated as:

$$\text{COH}^2 = \frac{\text{PHI}(1,1)^2 + \text{PHI}(2,1)^2}{\text{PHI}11 * \text{PHI}22}$$

For the more general case where a multichannel coherence is calculated, the remaining elements of the crosspower spectral matrix are placed in a matrix C. C is factored into a triangularized matrix S such that

$$C = (S^H)S$$

where H indicates the conjugate transpose of S. From this, an optimum filter set FIL is designed such that

$$(S^H)(S)(\text{FIL}) = \text{PHI}.$$

The multichannel coherence squared is then calculated as

$$\text{COH}^2 = \frac{(\text{PHI})(\text{FIL})}{\text{PHII}} .$$

Coherence is then a measure of the similarity of functions.

For this evaluation of the Iranian Long-Period Array noise field characteristics, multichannel coherencies (measured as coherence squared) were computed from ten noise samples using sites 2, 4, 5, 6, and 7 to predict site 1. The results were averaged together to eliminate minor day-to-day variations. The average coherence squared values are plotted in Figures III-8 to III-10. The vertical dashed lines in each plot represent the bandpass filter limits (0.023 - 0.059 Hz) used in RMS noise computations and signal processing and analysis. In each figure, the coherence squared has a peak at approximately the same frequency (0.06 - 0.07 Hz) as the microseismic peak of the noise RMS amplitude spectra. Robinson (Robinson, 1967) notes that microseismic noise is correlated to various degrees both in time and in space. This would explain the presence of this peak in the coherence squared plots.

Within the signal bandpass filter limits of 0.023 - 0.059 Hz, a second peak appears on the plots of coherence squared at approximately 0.035 Hz. The peak on the plot of the vertical component coherence squared is lower than the peaks on either of the coherence squared plots for the horizontal components. The level of coherence in the signal passband is high enough that multi-channel filter processing may be effective. In general, the shape and coherence levels shown in these figures are quite similar to those determined from the inner-ring sites of the Norwegian Seismic Array (Laun, Shen, and Swindell, 1973).

The frequency-wavenumber spectra are calculated in the following manner. In order to beamsteer an array so that it enhances plane waves from a particular direction, time delays are applied to the data to

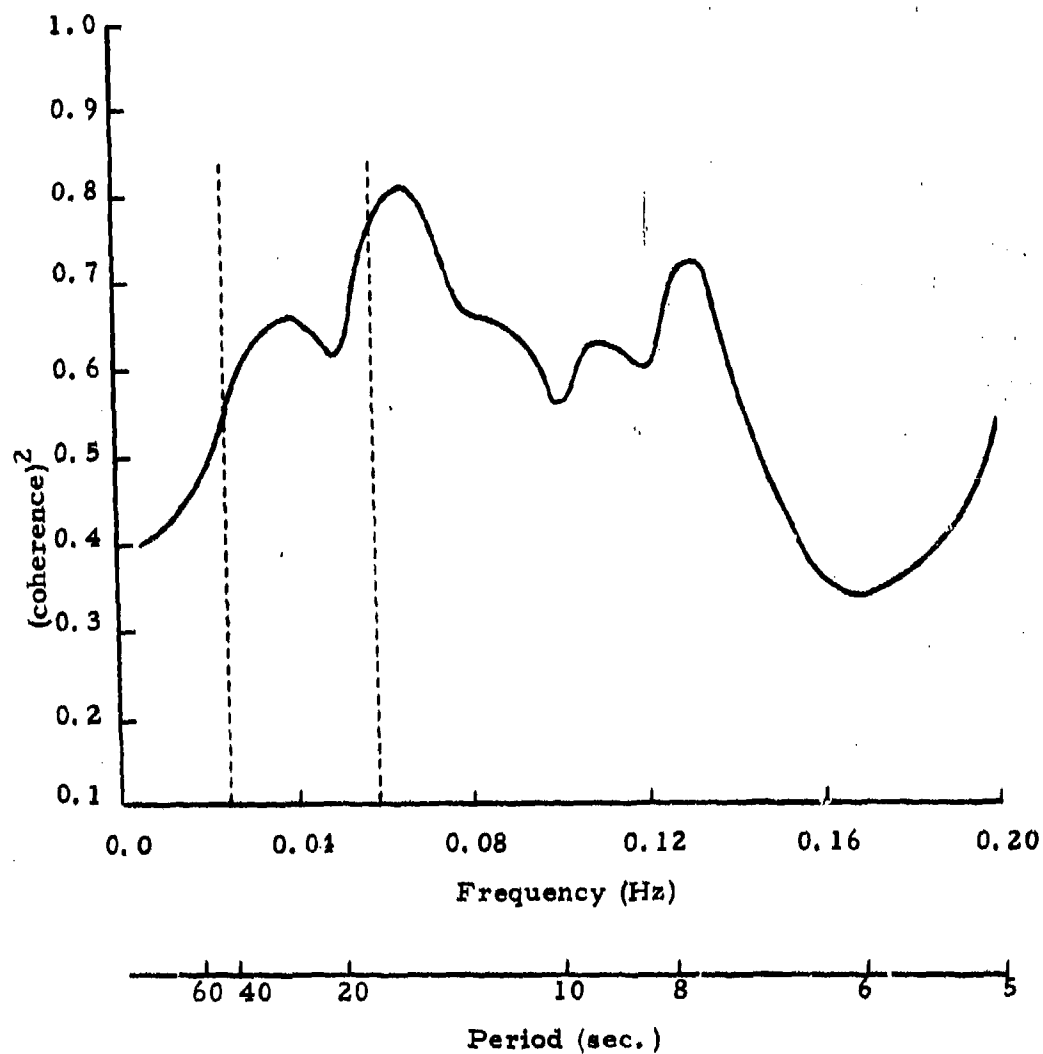


FIGURE III-8
VERTICAL COMPONENT AVERAGE MULTICHANNEL COHERENCE OF
10 ILPA NOISE SAMPLES
SITE 1 PREDICTED FROM SITES 2, 4, 5, 6, 7

The multichannel coherence squared is then calculated as

$$\text{COH}^2 = \frac{(\text{PHI})(\text{FIL})}{\text{PHI1}} .$$

Coherence is then a measure of the similarity of functions. For this evaluation of the Iranian Long-Period Array noise field characteristics, multichannel coherencies (measured as coherence squared) were computed from ten noise samples using sites 2, 4, 5, 6, and 7 to predict site 1. The results were averaged together to eliminate minor day-to-day variations. The average coherence squared values are plotted in Figures III-8 to III-10. The vertical dashed lines in each plot represent the bandpass filter limits (0.023 - 0.059 Hz) used in RMS noise computations and signal processing and analysis. In each figure, the coherence squared has a peak at approximately the same frequency (0.06 - 0.07 Hz) as the microseismic peak of the noise RMS amplitude spectra. Robinson (Robinson, 1967) notes that microseismic noise is correlated to various degrees both in time and in space. This would explain the presence of this peak in the coherence squared plots.

Within the signal bandpass filter limits of 0.023 - 0.059 Hz, a second peak appears on the plots of coherence squared at approximately 0.035 Hz. The peak on the plot of the vertical component coherence squared is lower than the peaks on either of the coherence squared plots for the horizontal components. The level of coherence in the signal passband is high enough that multi-channel filter processing may be effective. In general, the shape and coherence levels shown in these figures are quite similar to those determined from the inner-ring sites of the Norwegian Seismic Array (Laun, Shen, and Swindell, 1973).

The frequency-wavenumber spectra are calculated in the following manner. In order to beamsteer an array so that it enhances plane waves from a particular direction, time delays are applied to the data to

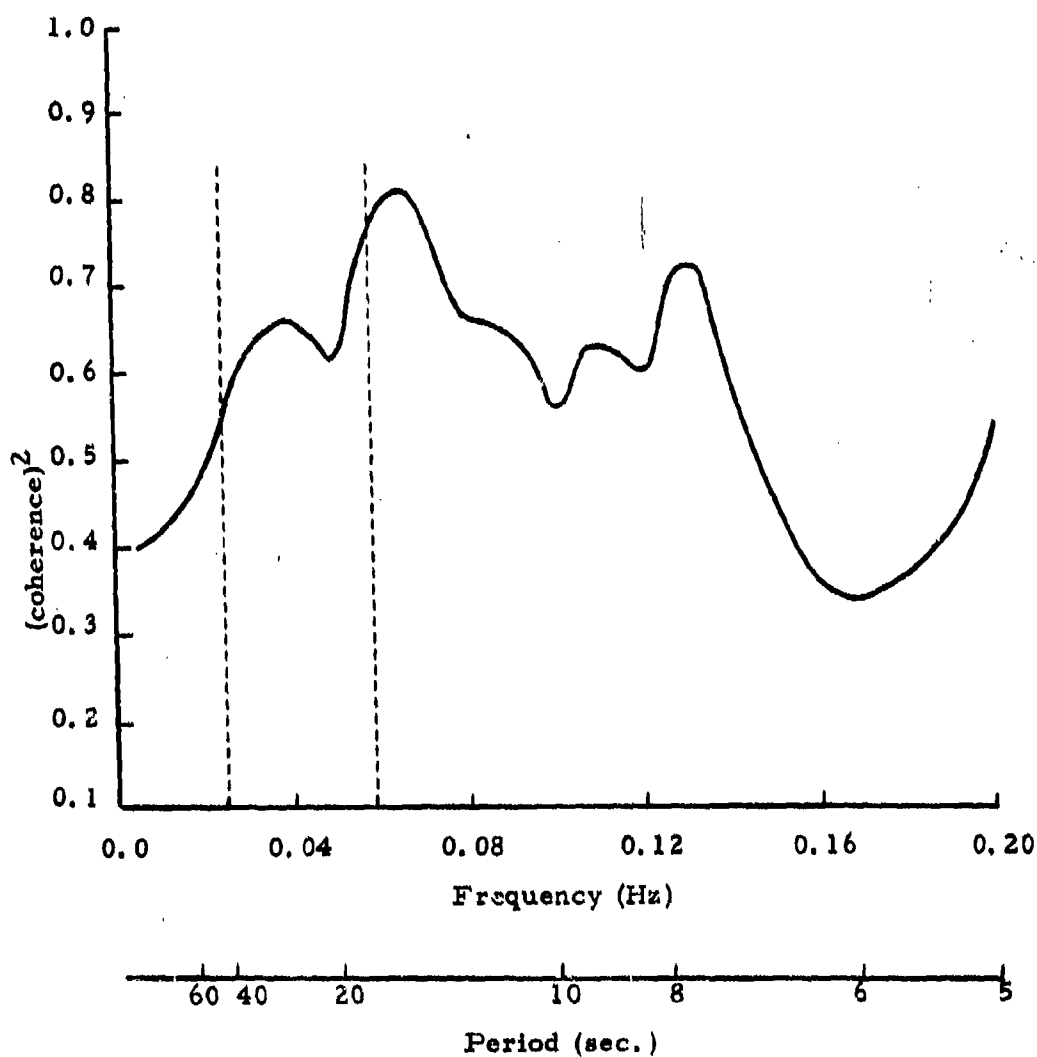


FIGURE III-8
VERTICAL COMPONENT AVERAGE MULTICHANNEL COHERENCE OF
10 ILPA NOISE SAMPLES
SITE 1 PREDICTED FROM SITES 2, 4, 5, 6, 7

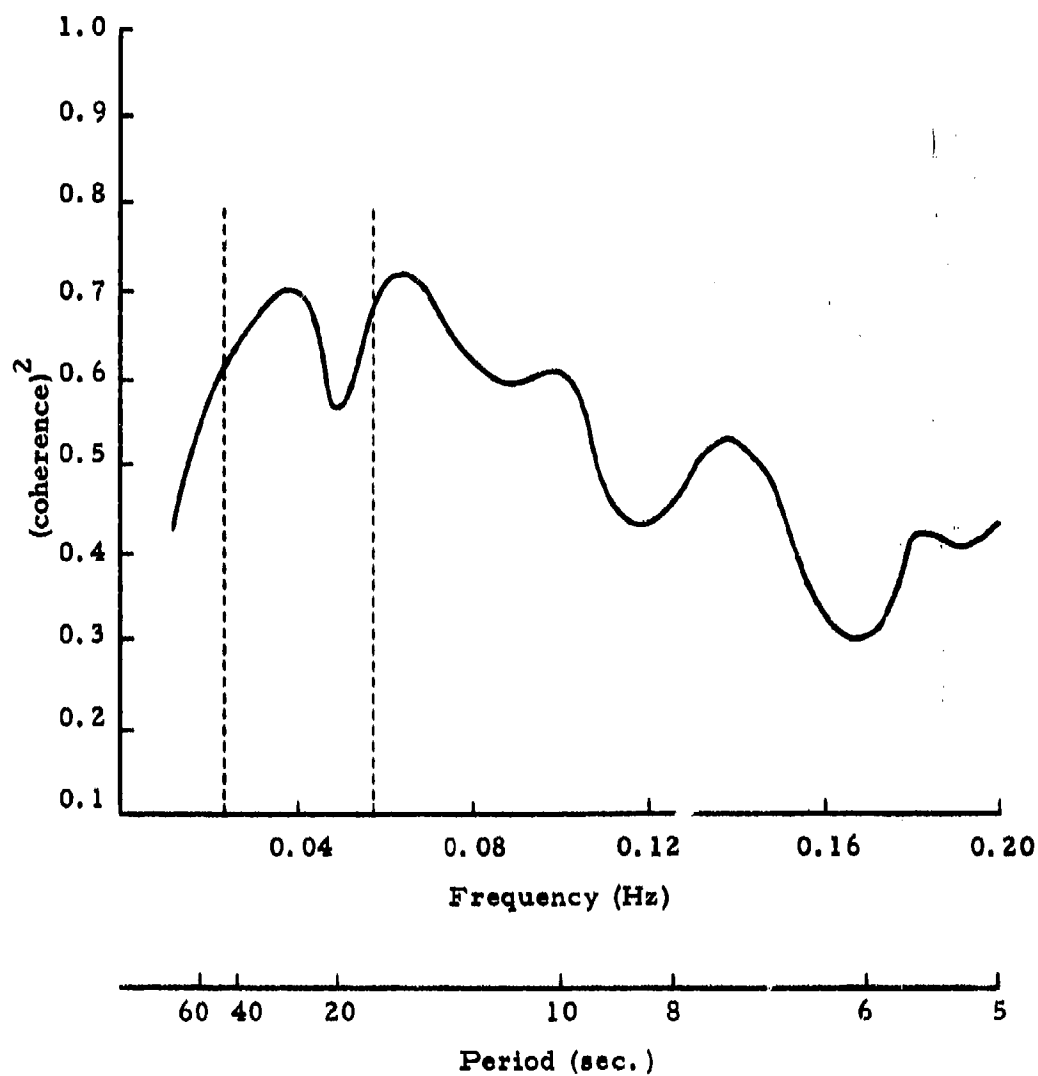


FIGURE III-9
NORTH COMPONENT AVERAGE MULTICHANNEL
COHERENCE OF 10 ILPA NOISE SAMPLES
SITE 1 PREDICTED FROM SITES 2, 4, 5, 6, 7

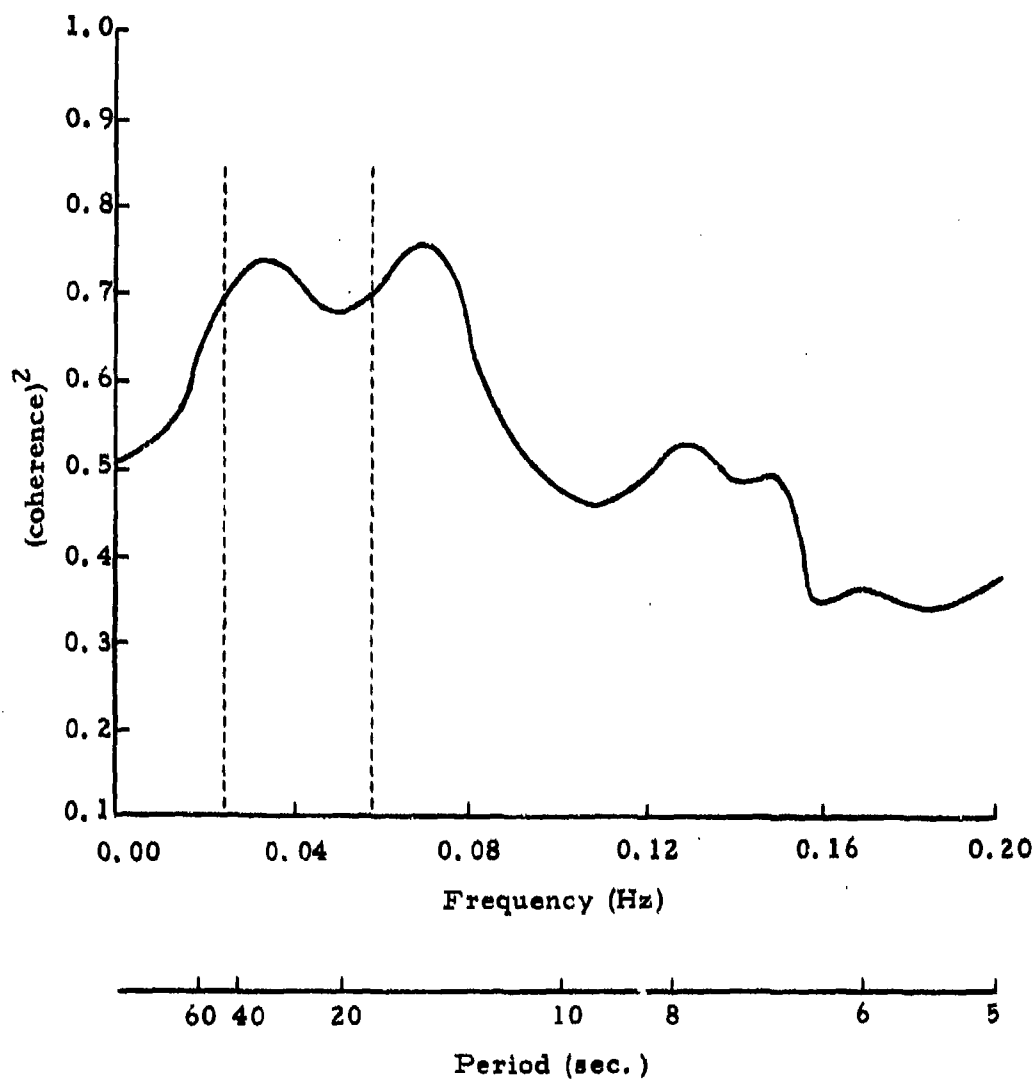


FIGURE III-10
 EAST COMPONENT AVERAGE MULTICHANNEL
 COHERENCE OF 10 ILPA NOISE SAMPLES
 SITE 1 PREDICTED FROM SITES 2, 4, 5, 6, 7

time-align the arrival of wavefronts associated with that direction. The application of a time delay τ_1 to the i^{th} channel is equivalent to applying a convolution filter $v_i(\tau) = \delta(\tau - \tau_1)$ whose Fourier transform is $\exp(i2\pi\vec{k} \cdot \vec{X}_1)$, where \vec{k} is the wavenumber space vector and \vec{X}_1 is the coordinate vector for site i . The beamsteer filter set for each wavenumber \vec{k} is specified by the vector

$$\vec{V} = \begin{bmatrix} \exp(i2\pi\vec{k} \cdot \vec{X}_1) \\ \exp(i2\pi\vec{k} \cdot \vec{X}_2) \\ \vdots \\ \exp(i2\pi\vec{k} \cdot \vec{X}_N) \end{bmatrix}$$

where N is the number of channels.

The power output of the filter set is then

$$CS(\vec{k}) = \vec{V}^T \Phi \vec{V}$$

or

$$HRS(\vec{k}) = \frac{1}{\vec{V}^T \Phi^{-1} \vec{V}}$$

where

CS = conventional frequency-wavenumber spectra

HRS = high-resolution frequency-wavenumber spectra

Φ = crosspower spectral matrix.

By incrementing the phase vector \vec{V} by appropriate discrete values, the wavenumber spectra for each corresponding point in \vec{k} space is computed. The spectra are next converted to dB units and for purposes of plotting the maximum value is assigned the symbol +A. Each power level below this maximum is assigned a symbol from A to Z, the dB decrement being user specified.

Figure III-11 shows a high-resolution frequency-wavenumber spectrum computed at a frequency of 0.03516 Hz using the vertical component data of event 1295. A signal was used for this figure to show how well the method can determine arrival azimuth and velocity. The azimuth of this event as computed from the epicenter coordinates is 38.2° . From the frequency-wavenumber spectrum of Figure III-11, the azimuth is 40.9° . The phase velocity measured from this figure is 3.6 km/sec., which appears to be a good Rayleigh wave phase velocity.

In order to investigate the question of propagating noise, high resolution frequency-wavenumber spectra were computed using each component of 91 noise samples. These spectra were computed at three frequencies: at 0.05859 Hz for the microseismic peak, at 0.04297 Hz for a representative signal-gate frequency, and at 0.01172 Hz for a point on the other side of the signal gate. The arrival azimuth and phase velocity of the peak value of each frequency-wavenumber spectrum were then measured. Table III-4 presents the number of occurrences by azimuth of the peak power of these frequency-wavenumber spectra. These values are tabulated without regard for the phase velocity associated with the measured azimuth.

The values in this table do not show any particular pattern as regards arrival azimuth. This would imply that there is no dominant source of propagating noise.

The next step in considering the question of propagating noise is to take into account the measured phase velocities. Propagating noise with phase velocities well below or above the beamforming velocities (4.0 km/sec. for Love, 3.5 km/sec. for Rayleigh) will be suppressed by the beamforming process. Therefore, those peaks in the frequency-wavenumber spectra which showed phase velocities below 3.2 km/sec. or above 4.5 km/sec. were removed from the results. The remainder were grouped by arrival azimuth.

Event Number 1295

Azimuth = 38.2° computed
from epicenter coordinates.

Azimuth = 40.9° measured
from frequency-wavenumber
spectrum.

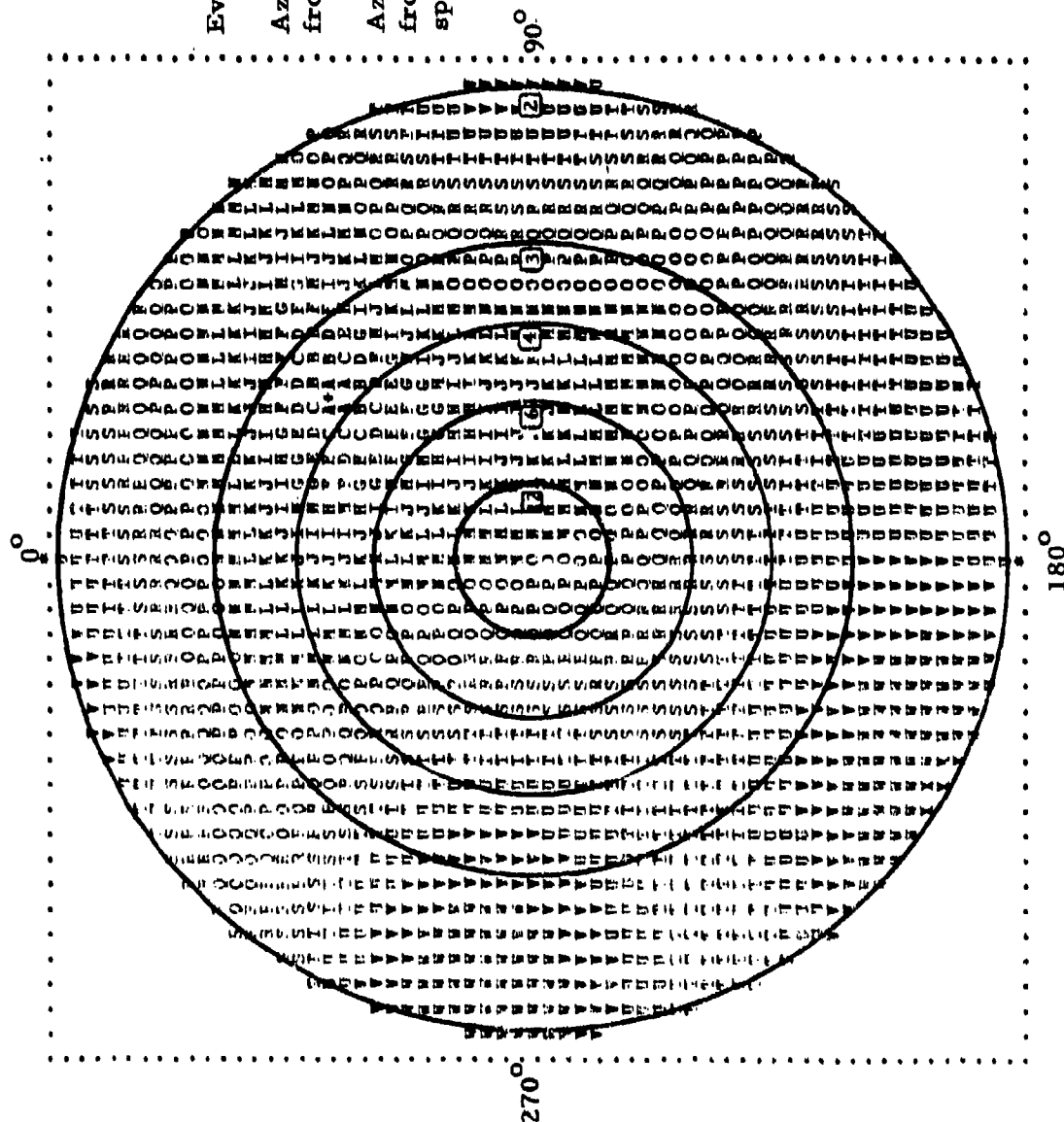


FIGURE III-11

FREQUENCY-WAVENUMBER SPECTRUM FOR VERTICAL COMPONENT OF EVENT 1295
COMPUTED AT FREQUENCY = 0.03516 Hz

TABLE III-4
NUMBER OF OCCURRENCES OF PEAK POWER BY AZIMUTH

<div> <div>Component</div> <div>Azimuth Range</div> </div>	Number of Occurrences of Peak Power								
	f = 0.01172 Hz			f = 0.04297 Hz			f = 0.05859 Hz		
	V	N	E	V	N	E	V	N	E
0-44	12	10	16	12	14	7	8	10	5
45-89	6	7	8	6	11	12	4	3	6
90-134	10	5	6	14	18	23	12	14	17
135-179	12	19	5	13	8	15	11	7	13
180-224	13	20	14	17	5	10	29	19	19
225-269	17	9	14	12	9	8	8	14	20
270-314	10	5	14	5	8	11	12	15	8
315-359	11	16	14	12	18	5	7	9	3

The results are shown in Figure III-12 for the frequency-wavenumber spectra computed at 0.01172 Hz, in Figure III-13 for the frequency-wavenumber spectra computed at 0.04297 Hz, and in Figure III-14 for the frequency-wavenumber spectra computed at 0.05859 Hz. The darkened area in each azimuth bin (0° - 45° , 45° - 90° , and so on) represents the number of times propagating noise was observed arriving at the array in that azimuth range at signal velocities. Bearing in mind the above description of how these figures were created, the following points should be noted from the figures:

- Figure III-12. There appears to be very little 0.01172 Hz propagating noise arriving at the array at signal velocities. What little there is shows no dominant range of source azimuths.
- Figure III-13. Approximately half of the frequency-wavenumber spectra computed at 0.04297 Hz had peaks with phase velocities in the signal velocity range, indicating that propagating noise may well form a significant part of the noise field at signal frequencies. On the vertical and east components, the majority of propagating noise arrivals had arrival azimuths between 90° and 225° , indicating noise sources lying to the south of the array, away from the general area of interest. On the north component, the majority of propagating noise arrivals had arrival azimuths between 315° and 45° .
- Figure III-14. Approximately half of the frequency-wavenumber spectra computed at 0.05859 Hz had peaks with phase velocities in the signal velocity range, indicating that propagating noise forms a significant portion of the microseismic noise peak. On all three components, the great majority of the propagating noise arrivals had source azimuths to the south of the array, away from the general area of interest.

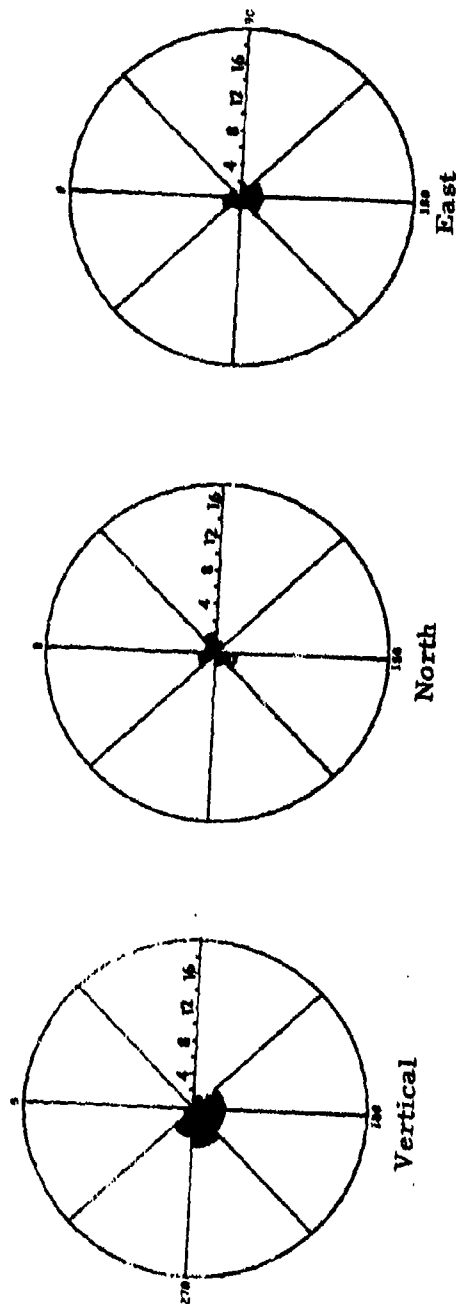


FIGURE III-12
 AZIMUTHAL DISTRIBUTION OF 0.01172 Hz PROPAGATING NOISE
 WITH PHASE VELOCITIES IN THE RANGE 3.2 - 4.5 KM/SEC.

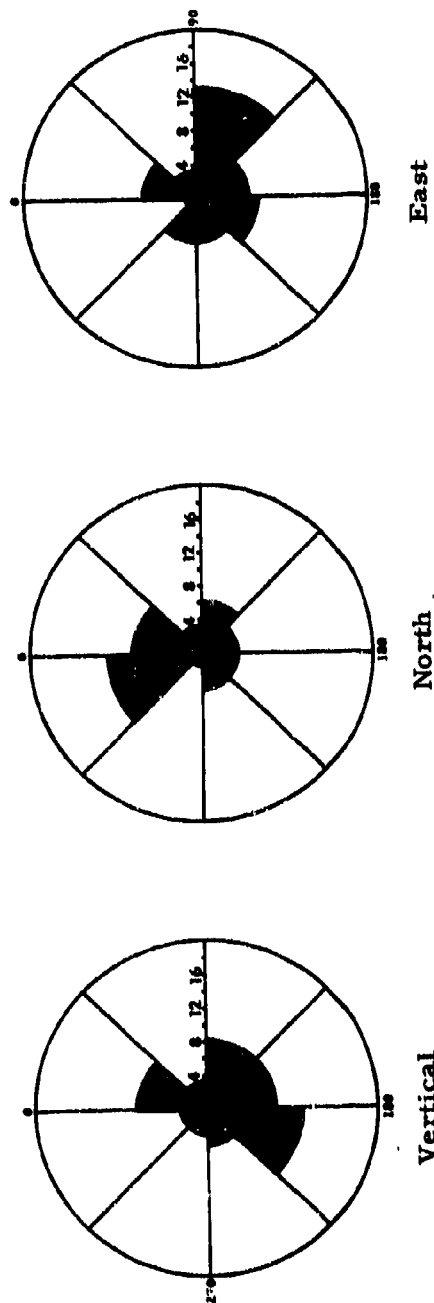


FIGURE III-13
AZIMUTHAL DISTRIBUTION OF 0.04297 Hz PROPAGATING NOISE
WITH PHASE VELOCITIES IN THE RANGE 3.2 - 4.5 KM/SEC.

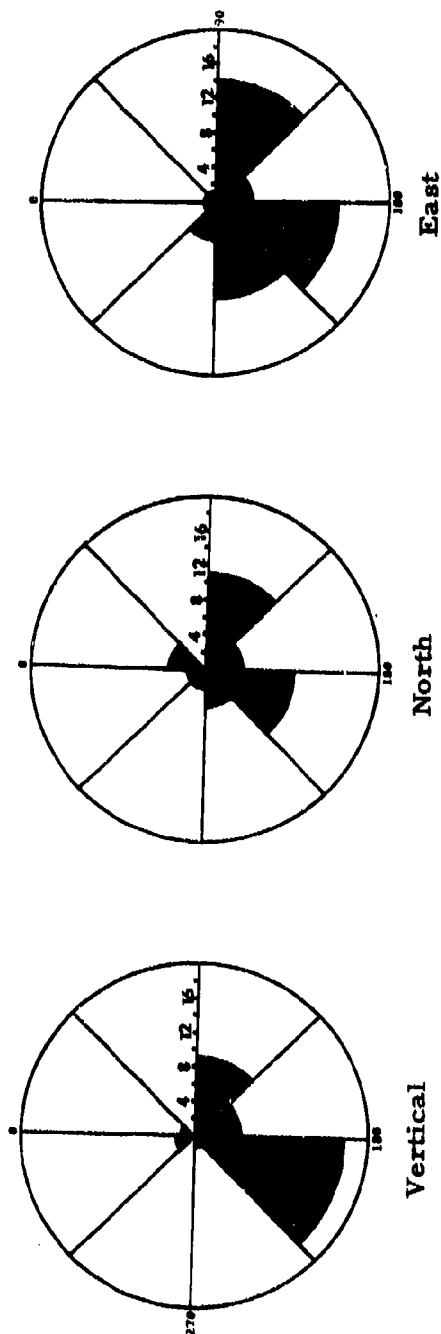


FIGURE III-14
 AZIMUTHAL DISTRIBUTION OF 0.05859 Hz. PROPAGATING NOISE
 WITH PHASE VELOCITIES IN THE RANGE 3.2 - 4.5 KM/SEC.

SECTION IV

SIGNAL ANALYSIS

A. DISCUSSION

This section will look at two aspects of signal analysis-gains in signal-to-noise ratio due to beamforming and site-to-site signal similarity. The first aspect is intended to indicate how much better than a single-site station at the same location the array will perform in terms of detection capability. To carry out this study, signal-to-noise ratios were computed for a suite of 100 events which were detected on both the reference site and beam data. The signal-to-noise ratio differences between the reference site data and beam data provide the array gain due to beamforming.

The site-to-site signal similarity computations are intended to describe how much alike a signal recorded at one site is to the same signal recorded at other sites. Local geologic differences from site to site and (unintended) differences in instrumentation can both affect the signal similarity. The less similar the signals are from site to site, the poorer the beamforming process will work, since the dissimilar portions of the signals will add randomly.

B. SIGNAL-TO-NOISE RATIO GAINS DUE TO BEAMFORMING

When the data recorded at the individual sites of an array are formed into beams, the signal-to-noise ratio of each component is increased due to suppression of noise. In the ideal case, the noise is purely random and is suppressed by a factor approximately equal to the square root of the number of sites used in the beamforming process. In practice, the noise is composed

of a random element and a propagating non-random element. This propagating element is suppressed to a lesser degree than the random element, the amount of suppression depending on how far off the beamforming azimuth its azimuth lies and how far from signal velocities is its velocity. Also, the beamforming process suppresses the signal to some extent. This is dependent on how accurate the computed time delays used to time-align the individual traces are and how similar the signals are from site to site. In particular, at some point close to the array, the plane-wave assumption used to compute these time delays must break down.

To obtain an estimate of the signal-to-noise ratio gains to be expected from the beamforming process, a suite of events was selected which were detected on both the reference site and beam traces and contained only noise in the time gate immediately preceding the signal arrival time. The signal-to-noise ratios for all components of the reference site and beam traces were then computed using the equation:

$$S/N \text{ (dB)} = 20. * \text{LOG}_{10} \frac{\text{zero-peak amplitude}}{\text{RMS noise}}$$

where 'zero-to-peak amplitude' is the amplitude of the largest peak of the signal waveform and 'RMS noise' is measured in the time gate immediately preceding the signal arrival. The gain due to beamforming is then simply the difference between the beam signal-to-noise ratio and the reference site signal-to-noise ratio.

The results in Table IV-1 are grouped on the basis of epicentral distance. The values in the column headed 'optimum gain' were computed from the following equation:

$$\text{Optimum Gain (dB)} = 20. * \text{LOG}_{10} \sqrt{\text{number of sites}}$$

TABLE IV-1
SNR GAINS IN dB DUE TO BEAMFORMING

Epicentral Distance	No. of Samples	Average No. of Sites	'Optimum' SNR Gain	Measured SNR Gains		
				V	T	R
0°-10°	23	4.6	6.6	2.9	2.5	0.5
10°-20°	23	5.4	7.4	7.8	4.8	4.6
20°-40°	18	4.7	6.7	7.3	4.9	5.0
40°-80°	36	5.0	7.0	6.0	4.0	3.2
10°-80°	77	5.0	7.0	6.9	4.4	4.0

where 'average number of sites' is the average number of sites used in beamforming. This table shows that beamforming gains for all components of events with epicentral distances less than ten degrees are very low. One possible explanation of this is that the plane-wave assumption used in beamforming to compute time delays fails for events with epicenters less than ten degrees from the array. A second possible explanation is that the fixed velocities used in beamforming (3.5 km/sec for Rayleigh, and 4.0 km/sec for Love) are not appropriate for beamforming close events.

The mean gains for the other ranges of epicentral distances remain fairly constant. This implies that the plane-wave assumption holds for events with epicentral distances greater than ten degrees.

Comparing the mean gains in Table IV-1 with the corresponding optimum gains, the data show that in general the mean gains for the horizontal components are lower than the optimum gains. This implies that some of the noise is propagating, since, as was described earlier, propagating noise is suppressed by beamforming to a lesser degree than is random noise.

An interesting feature of the data in Table IV-1 is that the radial component gains are lower than the vertical component gains. In Table IV-2 the signal-to-noise ratio gains are separated into the signal-to-noise gain due to RMS noise suppression and the signal-to-noise ratio loss due to peak signal suppression. From the data in this table it appears that the difference in signal-to-noise ratio gain between the vertical and radial components is due roughly equally to both lower RMS noise suppression and greater signal suppression on the radial component. The lower RMS noise suppression on the radial component in conjunction with lower RMS noise suppression on the transverse component relative to the vertical component implies that there is more propagating noise on the horizontal components than on the vertical components and that this noise is propagating as both Love and Rayleigh waves.

TABLE IV-2
NOISE AND SIGNAL SUPPRESSION IN dB
DUE TO BEAMFORMING

Epicentral Distance	RMS Noise Suppression			Peak Signal Suppression		
	V	T	R	V	T	R
0°-10°	6.5	5.0	5.0	3.5	2.5	4.5
10°-20°	8.8	5.8	7.1	1.0	1.0	2.5
20°-40°	7.5	6.0	6.5	0.2	1.1	1.5
40°-80°	6.6	5.0	5.6	0.6	1.0	2.4
10°-80°	7.5	5.4	6.2	0.6	1.0	2.2

C. SITE-TO-SITE SIGNAL SIMILARITY

The program used to measure site-to-site signal similarity requires as its input the edited time-domain data in the recorded vertical, north, east configuration. The program computes beamsteer time delays for each propagation mode by the equation:

$$D_i = \frac{(X_r - X_i) \sin \theta + (Y_r - Y_i) \cos \theta}{V}$$

where:

D_i is the time delay for site i

X_r and Y_r are the X and Y coordinates of the reference site

X_i and Y_i are the X and Y coordinates of the data site i

θ is the beamsteer azimuth, and

V is the velocity of the propagation mode.

The time delay, or lag, is considered to be negative if the signal arrives at data site i before it arrives at the reference site and positive if it arrives at the data site i after it arrives at the reference site.

The data at the various sites next have their trace means removed and are rotated to the beamsteer azimuth. Following this, the reference site zero-lag autocorrelation values are computed from:

$$\phi_{rr}(0) = \frac{1}{N} \sum_{k=1}^N X_r(k) X_r(k)$$

where $X_r(k)$ represents the reference site time series of N points sampled at Δt intervals. Correlation processing then continues for the data sites. The zero-lag autocorrelation $\phi_{ii}(0)$ is first computed. The cross-correlation functions $\phi_{ri}(\tau \Delta t)$ are next computed in the user-specified range for each lag τ . The zero-lag center point of the range of lags for a site is the beamsteer

lag for that site. The cross-correlation function for each site i at a lag τ is computed using

$$\phi_{ri}(\tau\Delta t) = \frac{1}{N} \sum_{k=1}^N X_r(k) X_i(k+\tau\Delta t).$$

After the autocorrelation values and cross-correlation functions are computed for each mode-component combination at each site, the cross-correlation matrix is searched for its maximum values and corresponding lags. For each combination the correlation coefficient is computed according to

$$CC_{ri} = \frac{\phi_{ri}(\Delta)}{[\phi_{rr}(0) \phi_{ii}(0)]^{\frac{1}{2}}}$$

where Δ is the lag at which $\phi_{ri}(\tau\Delta t)$ is a maximum and CC_{ri} is the correlation coefficient for the reference site and data site i . Correlation coefficient means are computed after all sites are processed.

Site-to-site signal similarity was investigated for each component by generating correlation coefficients between the reference site and the remaining six sites for a suite of large events. The results of computing correlation coefficients for 22 events ranging in bodywave magnitude from 4.7 to 6.3 and one typical noise sample are shown in Tables IV-3 to IV-5 for the vertical, transverse, and radial components of motion, respectively. Included in each table are the correlation coefficient for each site-event, the signal-to-noise ratio of the reference site data for each event, the average correlation coefficient for each event, and the correlation coefficient for each site averaged over all events. A dash indicates that data for that site-event were either not available or were not suitable for processing. No signal-to-noise ratio is listed for events whose noise gates contained other signals or spikes. Since no plane-wave anomalies were observed, cross-correlation

TABLE IV-3
CORRELATION COEFFICIENTS FOR VERTICAL COMPONENT

Event Number	Reference Site S/N (dB)	2	3	4	5	6	7	Event Average Correlation Coefficient
0766	36.2	0.80	----	0.83	0.65	0.80	0.95	0.81
0790	32.8	----	----	0.76	0.83	0.84	0.85	0.82
0824	19.6	0.54	----	0.56	0.65	0.77	0.20	0.53
0885	----	0.99	----	----	0.95	0.95	0.95	0.96
0886	60.2	0.84	----	0.82	0.82	0.93	0.78	0.84
0890	36.7	0.89	----	0.84	0.87	0.94	0.81	0.87
0900	38.0	0.84	----	0.84	0.80	0.95	0.78	0.84
1265	----	0.51	----	0.75	0.71	----	0.33	0.57
1295	31.4	0.93	----	0.90	0.93	0.91	0.89	0.91
1296	74.4	0.81	----	0.58	0.74	0.86	0.92	0.78
1321	45.1	0.86	----	----	----	0.84	0.81	0.83
1331	55.1	0.80	----	----	----	0.88	0.70	0.79
1395	34.9	0.85	----	----	0.77	0.90	0.91	0.86
1406	39.5	0.85	0.92	----	0.94	0.95	0.82	0.90
1413	50.4	0.91	0.96	----	0.92	----	0.87	0.91
1524	56.2	0.86	0.90	0.78	----	0.91	----	0.86
1544	33.9	0.92	0.95	----	----	----	0.82	0.90
1555	35.4	0.84	0.85	----	0.78	0.89	0.64	0.80
1574	30.5	0.76	0.87	----	----	0.82	0.62	0.77
1621	54.4	----	0.88	0.83	----	----	0.72	0.81
1625	33.1	----	----	0.87	0.84	0.91	0.78	0.85
1628	31.8	----	----	0.82	0.94	0.75	----	0.83
Day 170 (1976)	----	0.26	----	-0.17	-0.15	-0.14	-0.19	-0.08
Noise Sample								
Site Average (Excluding Events 824 and 1265)	----	0.86	0.90	0.81	0.84	0.88	0.81	----

TABLE IV-4
CORRELATION COEFFICIENTS FOR TRANSVERSE COMPONENT

Event Number	Reference Site S/N (dB)	2	3	4	5	6	7	Event Average Correlation Coefficient
0766	41.3	0.81	----	0.87	0.89	0.96	0.92	0.89
0790	38.7	----	----	0.75	0.86	0.94	0.95	0.88
0824	22.0	0.71	----	0.54	0.65	0.78	0.62	0.66
0885	----	0.82	----	----	0.86	0.95	0.79	0.86
0886	47.1	0.81	----	0.81	0.80	0.97	0.82	0.84
0890	36.7	0.89	----	0.84	0.87	0.96	0.88	0.89
0900	41.5	0.82	----	0.75	0.76	0.94	0.82	0.82
1265	----	0.57	----	0.62	0.55	----	0.60	0.58
1295	37.0	0.92	----	0.76	0.92	0.84	0.86	0.86
1296	68.3	0.85	----	0.81	0.84	0.89	0.85	0.85
1321	50.4	0.94	----	----	----	0.96	0.94	0.95
1331	45.6	0.85	----	----	----	0.93	0.83	0.87
1395	39.0	0.78	----	----	0.88	0.93	0.88	0.87
1406	36.3	0.72	0.89	----	0.68	0.89	0.66	0.77
1413	47.0	0.93	0.96	----	0.91	----	0.89	0.92
1524	57.5	0.85	0.89	0.86	----	0.91	----	0.88
1544	45.1	0.97	0.86	----	----	----	0.95	0.92
1555	30.4	0.87	0.87	----	0.82	0.92	0.96	0.97
1574	49.9	0.97	0.98	----	----	0.98	0.80	0.86
1621	60.3	----	0.97	0.87	----	----	0.92	0.92
1625	28.8	----	----	0.65	0.68	0.93	0.72	0.74
1628	34.2	----	----	0.75	0.95	0.58	----	0.76
Day 170 (1976)	----	0.10	----	0.06	-0.14	0.21	0.21	0.09
Noise Sample								
Site Average (Excluding Events 824 and 1265)	----	0.86	0.92	0.79	0.84	0.91	0.86	----

TABLE IV-5
CORRELATION COEFFICIENTS FOR THE RADIAL COMPONENT

Event Number	Reference Site S/N (dB)	2	3	4	5	6	7	Event Average Correlation Coefficient
0766	33.9	0.78	----	0.76	0.74	0.75	0.89	0.78
0790	36.5	----	----	0.73	0.72	0.83	0.91	0.80
0824	23.6	0.70	----	0.55	0.66	0.75	0.57	0.65
0885	----	0.99	----	----	0.95	0.94	0.94	0.95
0886	50.3	0.79	----	0.82	0.79	0.87	0.74	0.80
0890	34.5	0.85	----	0.85	0.83	0.91	0.78	0.84
0900	37.4	0.76	----	0.81	0.74	0.93	0.69	0.79
1265	----	0.59	----	0.69	0.72	----	0.53	0.63
1295	34.3	0.82	----	0.75	0.91	0.82	0.86	0.83
1296	73.3	0.80	----	0.47	0.63	0.77	0.76	0.69
1321	49.2	0.84	----	----	----	0.78	0.66	0.76
1331	47.2	0.82	----	----	----	0.83	0.68	0.78
1395	36.2	0.56	----	----	0.58	0.68	0.89	0.68
1406	37.7	0.86	0.86	----	0.87	0.90	0.85	0.87
1413	50.7	0.92	0.94	----	0.85	----	0.90	0.90
1524	56.4	0.67	0.84	0.74	----	0.87	----	0.78
1544	38.2	0.78	0.93	----	----	----	0.69	0.80
1555	39.0	0.82	0.79	----	0.65	0.79	0.68	0.74
1574	38.2	0.41	0.60	----	----	0.77	0.42	0.55
1621	53.5	----	0.87	0.77	----	----	0.50	0.71
1625	32.8	----	----	0.80	0.73	0.93	0.69	0.79
1628	32.5	----	----	0.74	0.93	0.81	----	0.83
Day 170 (1976)	----	-0.18	----	0.17	-0.17	0.21	0.20	0.05
Noise Sample								
Site Average (Excluding Events 824 and 1265)	----	0.78	0.83	0.75	0.78	0.83	0.75	----

lag data are omitted. The data in these tables are interpreted from the standpoint that a correlation coefficient of 1 computed using data recorded at the reference site and data site i would indicate that the waveforms at these sites are identical, a correlation coefficient of zero would indicate that the waveforms at these sites are wholly unlike each other, and a correlation coefficient of -1 would indicate that the waveforms at these sites differ by a phase shift of 180° .

The following points should be noted from this data:

- Events with low correlation coefficients were reprocessed using site 2 as reference to determine if site 1 was producing anomalous values. The results were not significantly different.
- The low correlation coefficients for event 824 appear to be a result of low signal-to-noise ratio. Note that this event has the lowest signal-to-noise ratio of the suite of events.
- Event 1265 also displayed low correlation coefficients. Plots of the raw data of this event showed the data to be corrupted with high frequency noise. Examination of the field tape logs for this time period revealed that transmission errors occurred during the recording of this event.
- The transverse component yielded larger correlation coefficients than either the vertical or radial components, being greater than 0.8 for all large events.
- The radial component yielded on average the lowest correlation coefficients. This is perhaps reflected in the results of peak signal suppression due to beamforming the radial component as shown in Table IV-2.

- Overall, sites 3 and 6 yield better correlation coefficients with the reference site than do the other sites. Site 4 on the average, yields the lowest correlation coefficients.
- As expected, the noise sample yielded very low correlation coefficients.
- The peak signal suppressions noted in Table IV-2 appear to be reflected by the less than perfect site-to-site similarities.

SECTION V

ILPA DETECTION CAPABILITY

A. DISCUSSION

In past evaluation tasks, detection statistics were derived from an event population for every member of which a clear detection/non-detection decision could be made; i. e., the analyst could state that he either saw the sought-for signal or he saw seismic noise. Unfortunately, the world does not always present the analyst with such a clear-cut case. Mixed events, system failures resulting in no data being recorded, and malfunctions all tend to obscure the detection capability picture.

The term 'mixed event' refers to the case where the sought-for signal is obscured or completely masked by a second signal. This can happen either when the two signals arrive at the station at essentially the same time or when a larger signal arrives before the signal under analysis, burying this signal in its coda. The term 'system failure' refers to the total shutting down of the station so that no data is recorded. The term 'malfunction' refers to any partial failure of the system, from sensor unit to reception of data at the Seismic Data Analysis Center, which causes degradation of the seismic data.

The problem of mixed events is often difficult for the analyst to resolve and is probably the major source of false alarms. (The term 'false alarm' in this context means declaring a detection when in fact the observed signal is from an event other than that under analysis.) When a signal is observed in the time gate of the event under analysis, the analyst first checks the waveforms on the three components of motion to see that their inter-relationships are correct. If still in doubt, the analyst checks available event lists to see whether any other reported event could have arrived in the signal gate. In general, the analyst declares a detection if a dispersed signal

is observed having the correct inter-relationships between the Love and Rayleigh waves and if no other event has been reported which could be mistaken for the event under analysis.

Since mixed events and (secondarily) events for which no data were recorded or which contained malfunctions are a fairly common problem, the Iranian Long-Period Array detection capability estimates are calculated in two ways. The first of these is termed the absolute detection capability estimate. When computing this estimate, all mixed events, events for which no data were recorded, and events containing malfunctions are counted as non-detections when forming the detection statistics. This approach gives a real-world detection capability estimate.

The second of these estimates is termed the conditional detection capability estimate. When computing this estimate, all mixed events, events for which no data were recorded, and events containing malfunctions are rejected from the detection statistics. This approach gives an ideal detection capability estimate. The value of this ideal estimate is that it shows the detection capability improvement possible if the reliability of the instrumentation can be improved and if methods of separating mixed events can be found.

The number used to represent detection capability is the 50 percent detection threshold, denoted by ' m_{b50} '. The 50 percent detection threshold is the bodywave magnitude for which the probability of detection is 0.5. It is computed by fitting the Gaussian probability function to the detection statistics by a maximum likelihood method (Ringdal, 1974). Hereafter, this will be referred to as the maximum likelihood curve.

It must be kept in mind that, since the data base was derived from the NORSAR and NEIS event bulletins, all detection capability estimates are in terms of a combined 'NORSAR - NEIS' m_b unit. This fact is important,

since NORSAR m_b units are not the same as those from the National Earthquake Information Service (NEIS) event lists.

Depending on the quantity of data available, one of three levels of confidence is placed on each 50 percent detection threshold. If a 50 percent detection threshold is given to two decimal places (e.g., $m_{b50} = 4.56$), sufficient detection statistics were available to compute a reliable detection capability estimate. If a 50 percent detection threshold is enclosed in parentheses and given to only one decimal place, (e.g., $m_{b50} = (4.6)$) the detection statistics were sparse and the detection capability estimate can be considered to be only a first approximation. Finally, if a 50 percent detection threshold is expressed as greater than some value (e.g., $m_b > 5.0$), the detection statistics were too sparse to allow fitting of a maximum likelihood curve. In most cases, this is due to a lack of detected events. When this occurred, the value given is the m_b of the largest non-detected event.

B. ILPA LONG-PERIOD DETECTION CAPABILITY ESTIMATES

This subsection examines the estimates of detection capability made from the accumulated detection statistics for the reference site and beam data. The criteria used by the analyst which determine whether an event was detected are:

- The presence of dispersion in the signal gate.
- A peak in the dispersed wavetrain 3 dB or more above any peak outside the dispersed wavetrain and inside a time gate starting 600 seconds before the predicted Love wave arrival time and ending 600 seconds after the estimated Rayleigh wave end time.
- Occurrence of signal onset within ± 180 seconds of the predicted signal onset time.

- Detection of the signal on at least two of the three components of motion.

These criteria were used as a guide to aid the analyst in determining the detection status of processed events. The first criterion was always followed for the events processed in this evaluation, since this is the primary visual difference between seismic signals and noise. The second criterion was occasionally disregarded, since bodywaves such as SS or isolated noise pulses would be at times visible within the specified time gate. If the event under analysis was visible, it was declared detected even if one of these was also visible. The third criterion was also occasionally not followed. When a waveform in the signal gate was observed to arrive later than this criterion allowed, the event lists were checked to ensure that this waveform was not due to some other event. If no other event could be found whose surface waves would arrive at the observed arrival time, the event under analysis was called a detection. The last criterion was rigidly followed, since it was imposed to reduce the probability of erroneously declaring an event to be detected.

The various detection capability estimates made for this evaluation are shown in Figures V-1 to V-4. Each 'sub-figure' of these figures consists of two parts. The upper part consists of a histogram showing the number of detected and non-detected events as a function of body-wave magnitude (m_b) for the particular data subset under consideration. The lower part shows the detection probability derived from these detection statistics as a function of bodywave magnitude. The percentage of events detected at each m_b value is represented by an asterisk. The maximum likelihood curve fitted to these detection percentages is represented by a solid line. The 90 percent confidence limits of this curve are represented by dashed lines. The values for 'MB50' and 'MB90' shown on the figures represent the 50 and 90 percent detection thresholds respectively, as determined by the

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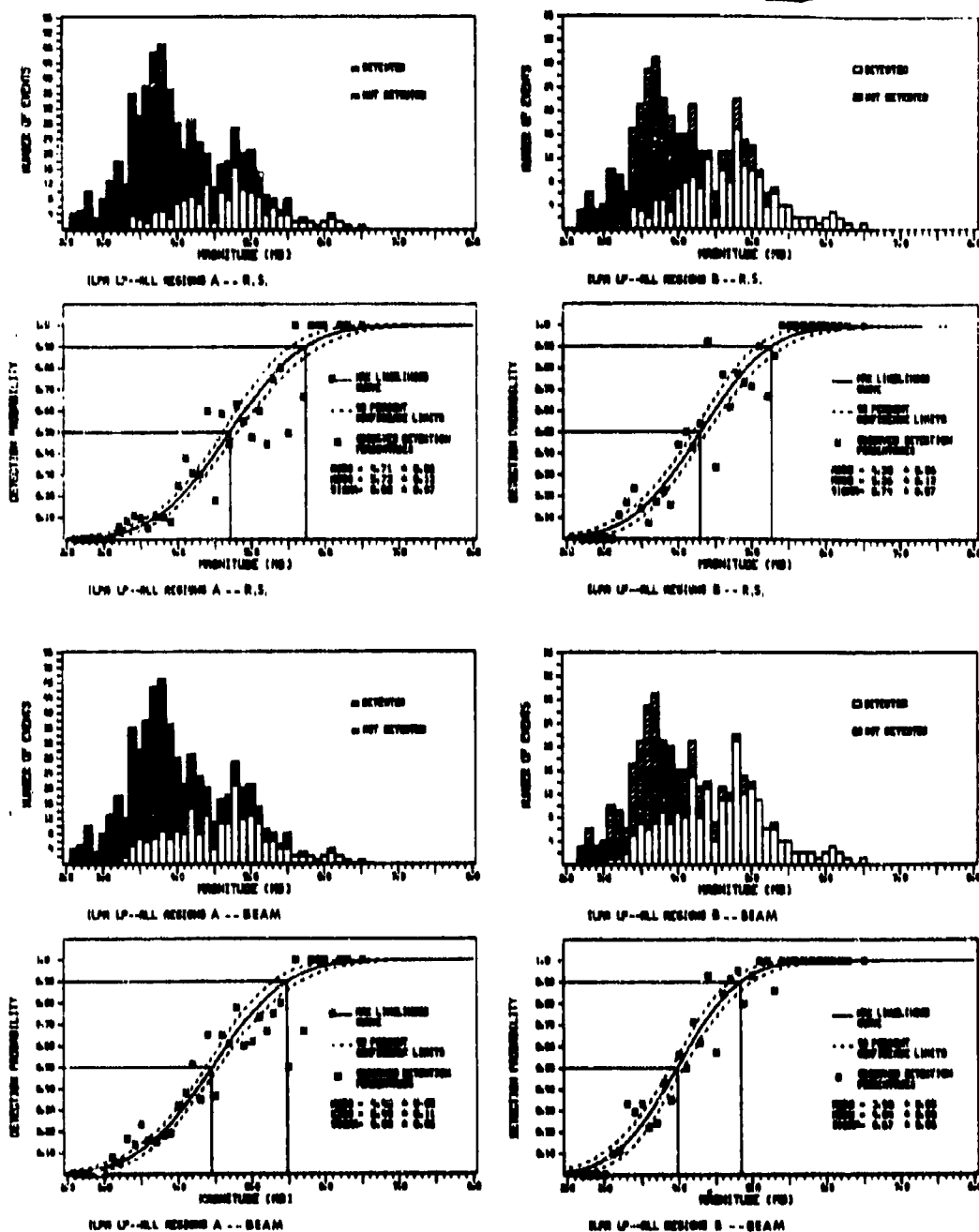


FIGURE V-1
ILPA LONG-PERIOD REFERENCE SITE AND
BEAM DETECTION STATISTICS
ALL REGIONS A AND B

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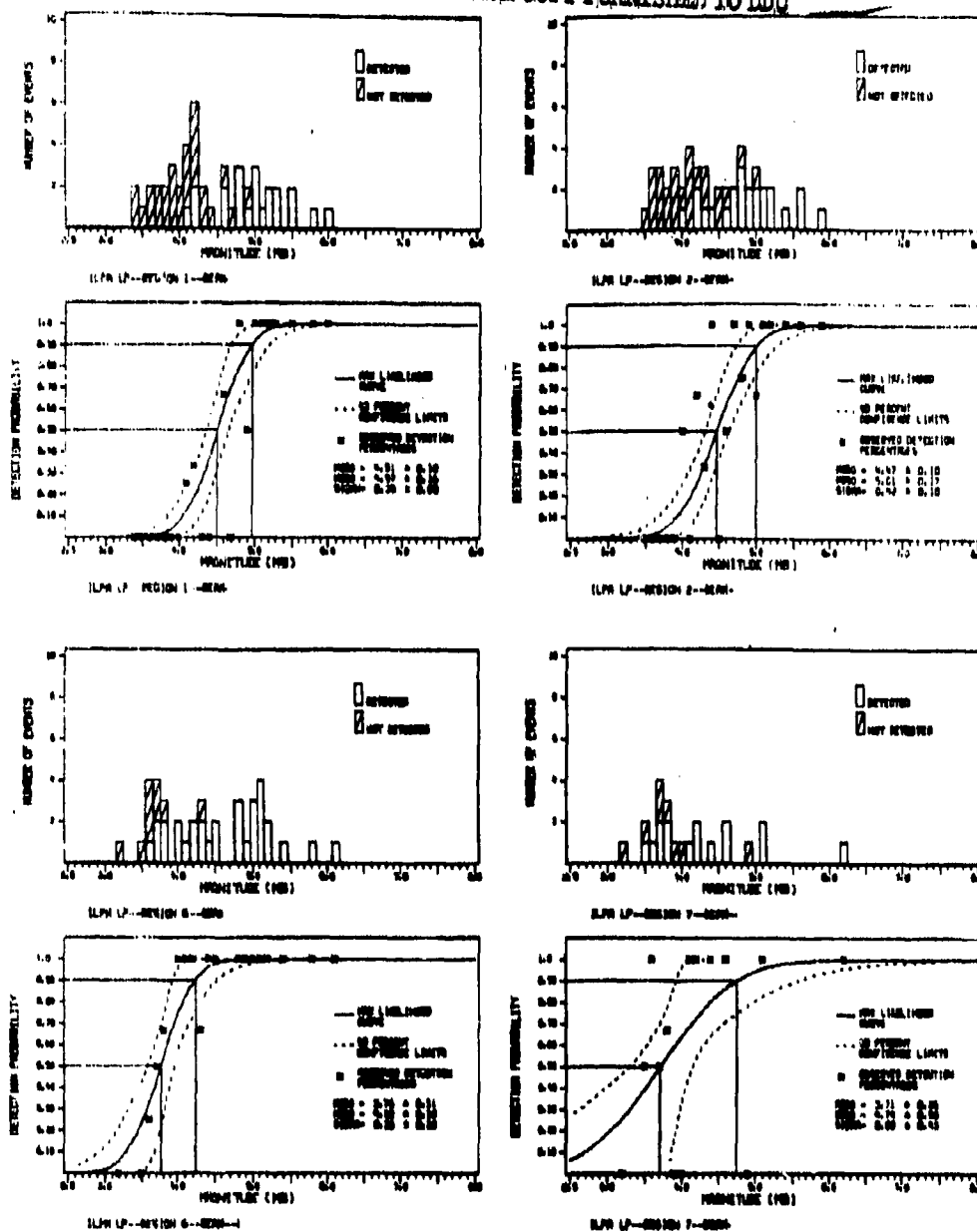


FIGURE V-2
ILPA LONG PERIOD BEAM DETECTION STATISTICS
REGIONS 1, 2, 6, AND 7

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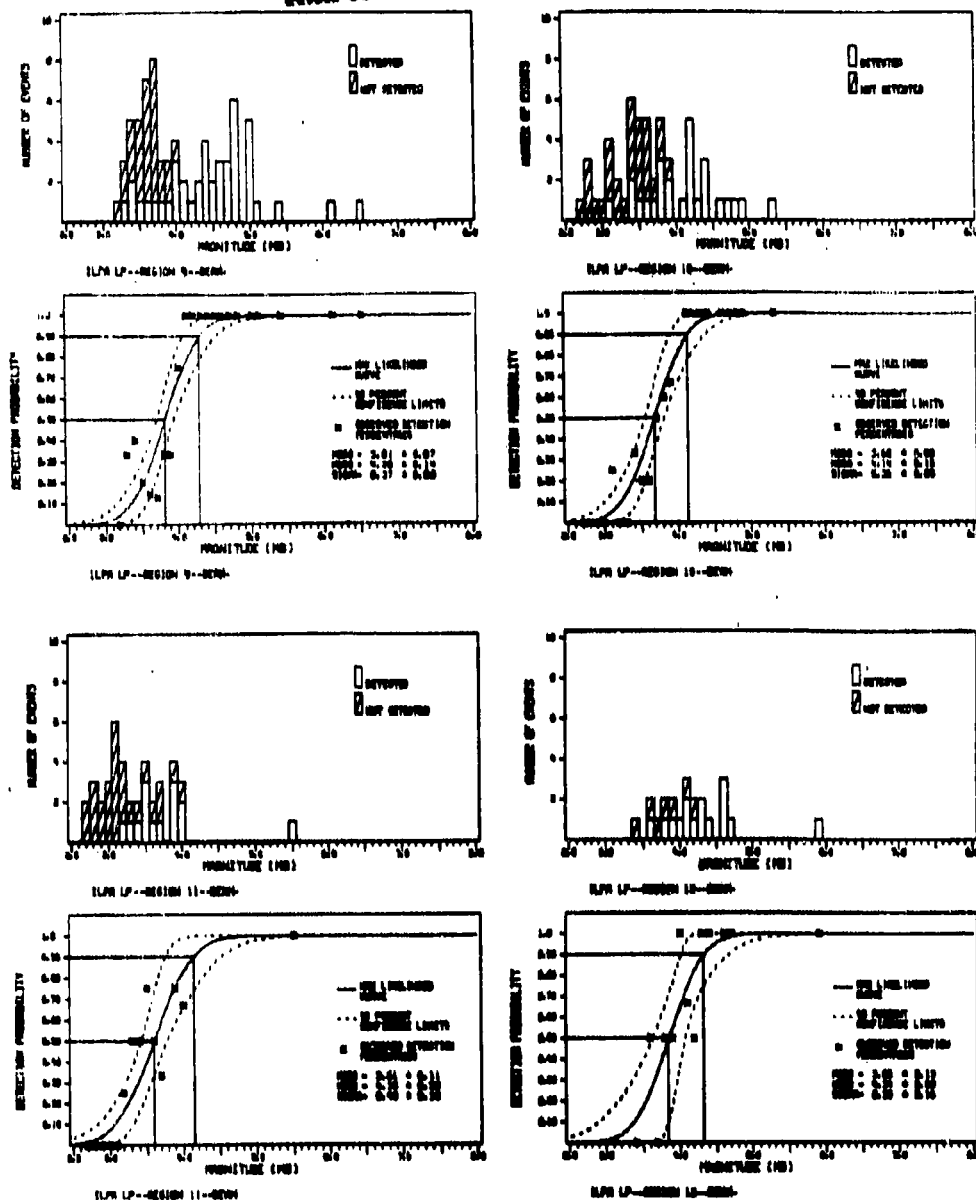


FIGURE V-3
ILPA LONG-PERIOD BEAM DETECTION STATISTICS
REGIONS 9, 10, 11, AND 12

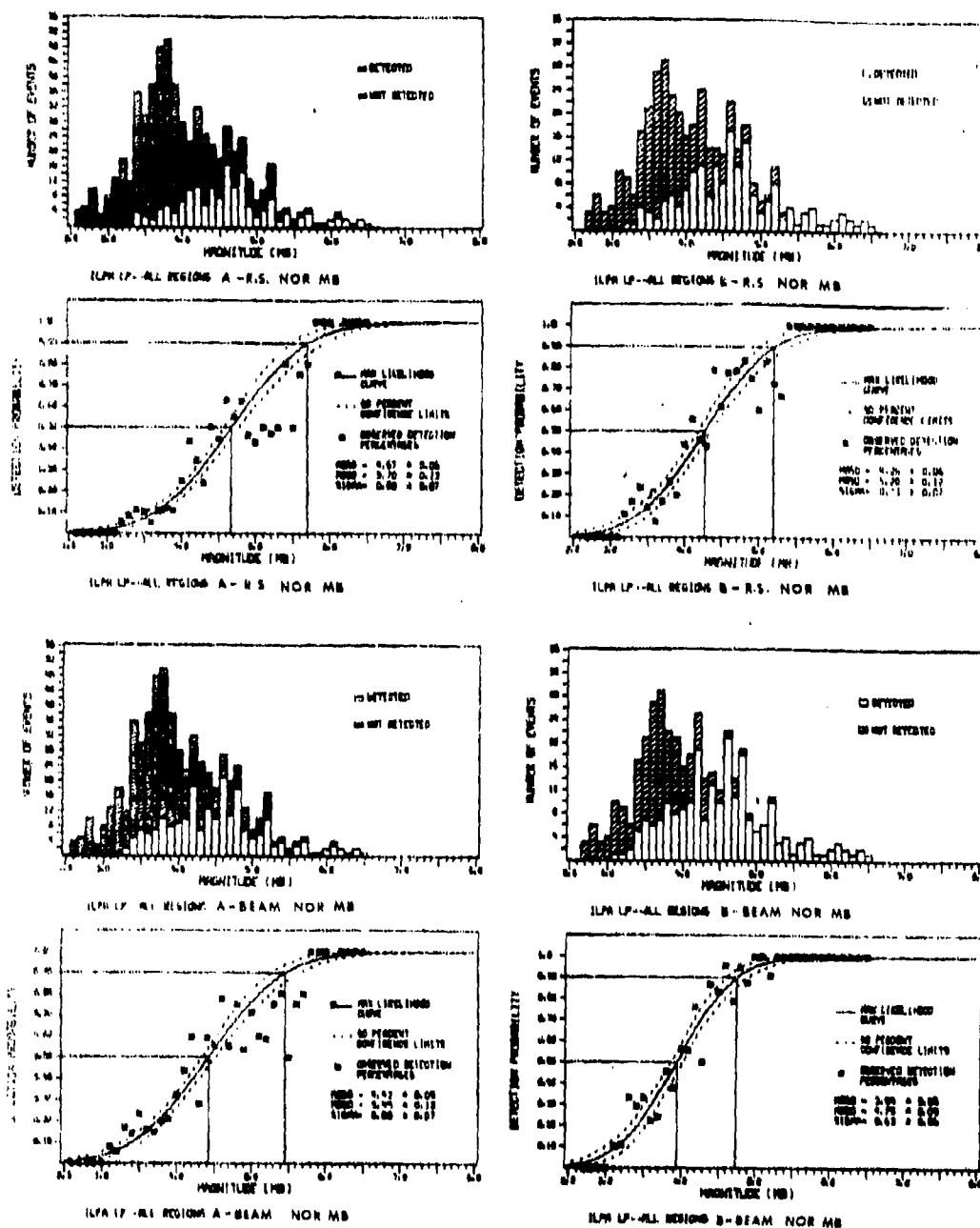


FIGURE V-4

ILPA LONG-PERIOD REFERENCE SITE AND
BEAM DETECTION STATISTICS
ALL REGIONS A AND B
(NORSAR m_b VALUES)

maximum likelihood curve. Finally, the value given for 'SIGMA' is the standard deviation of the Gaussian probability function for the maximum likelihood curve.

Figure V-1 presents the reference site and beam detection capability estimates using the detection statistics of all the regions. These were made in two ways. In the first, denoted by 'ALL REGIONS A', mixed events, events for which no data were recorded, and events containing malfunctions were counted as non-detections. This forms the previously defined absolute detection capability estimate. In the second, denoted by 'ALL REGIONS B', mixed events, events for which no data were recorded, and events containing malfunctions were rejected from the detection statistics. This forms the previously defined conditional detection capability estimate.

Figures V-2 and V-3 show the detection capability estimates for the beam data on a regionalized basis. These estimates are conditional detection capability estimates. The paucity of detection statistics makes these regionalized estimates valid as first approximations only.

The detection statistics of Figures V-1 to V-3 were derived from earthquakes whose event parameters were taken from either the NORSAR or the NEIS event bulletins. Since the two event bulletins partially overlap in the time frame each covers, it was possible to compare the m_b values that each reports. A total of 518 Eurasian events were found to be reported by both event bulletins. By fitting a straight line to the NORSAR m_b - NEIS m_b pairs so found, using an algorithm which treats neither variable as dependent, the following relationship between the two types of m_b was derived:

$$\text{NORSAR } m_b = 1.11 \text{ NEIS } m_b - 0.71 \quad (\text{variance} = 0.03).$$

Figure V-4 was formed by converting all NEIS-reported m_b values in the data base to NORSAR m_b values using the above relationship. Like Figure V-1,

this figure shows the single-site and beam detection capability estimates using 'ALL REGIONS A' and 'ALL REGIONS B' detection statistics. The purpose of this is to estimate the effects of the m_b conversion on the detection capability estimates.

The various detection capability estimates are summarized in Table V-1. Since the prime purpose of this section is to estimate the array detection capability, no regionalized reference site detection capability estimates were made. The following points should be noted from the data presented in Table V-1:

- Mixed events, events for which no data were recorded, and malfunctions raised the 50 percent detection threshold by 0.4 - 0.5 m_b units.
- The beamforming process lowered the 50 percent detection threshold by 0.25 - 0.30 m_b units.
- The conversion of NEIS m_b values to NORSAR m_b values had essentially no effect on the ILPA detection capability.
- The regionalized ILPA detection capability estimates can be considered as first approximations only, due to the limited detection statistics available.

It should be noted that, although the conversion of NEIS m_b values to NORSAR m_b values had essentially no effect on these detection capability estimates, the authors feel that in any future work this matter should be considered again. For the data base used in this report, the ratio of NORSAR events to NEIS events was approximately 4 to 1. Future increases in the data base will raise the number of NEIS events in the data base (since the NORSAR event bulletin ceased being issued 30 September 1976) and hence will increase the relative effect of NEIS m_b values on the detection capability estimates.

TABLE V-1
ILPA LONG-PERIOD DETECTION CAPABILITY

Region	NORSAR & NEIS m_b 's		NORSAR m_b 's		Mean Distance in Degrees
	Reference	Beam	Reference	Beam	
All Regions A	4.71	4.46	4.67	4.42	36.5
All Regions B	4.30	3.98	4.26	3.94	
1	----	(4.5)	----	(4.5)	71.8
2	----	(4.5)	----	(4.4)	69.6
5	----	>4.0	----	>4.3	40.7
6	----	(3.8)	----	(3.7)	36.9
7	----	(3.7)	----	(3.7)	31.6
9	----	(3.8)	----	(3.8)	8.6
10	----	(3.7)	----	(3.7)	17.2
11	----	(3.6)	----	(3.6)	24.7
12	----	(3.8)	----	(3.8)	53.9

Note:

1. Detection capability is estimated in terms of the 50 percent detection threshold.
2. All Regions A - Mixed, no data recorded, and malfunctions are counted as non-detections.
3. All Regions B - Mixed, no data recorded, and malfunctions are rejected from detection statistics.

SECTION VI

EARTHQUAKE-PRESUMED EXPLOSION DISCRIMINATION

A. DISCUSSION

This section considers the question of discriminating between earthquakes and presumed nuclear explosions using long-period data. The discrimination method used is the surface-wave magnitude (M_s) versus bodywave magnitude (m_b) plot. This plot of M_s versus m_b is expected to function as an earthquake-presumed nuclear explosion discriminant since, for a given m_b , an explosion generates much lower Rayleigh and Love waves than does an earthquake. (Theoretically, an explosion should generate no Love waves, since the source is completely compressional. However, some Love wave energy is radiated from tectonic strain release (Sun, 1977) subsequent to the explosion.) Therefore, a plot of M_s versus m_b can be expected to show a separation of the data points into an earthquake population and an explosion population.

The data base for this discrimination study is comprised of all events which were visually detected on bandpass-filtered (0.023 - 0.059 Hz passband) plots.

B. COMPUTATION OF SURFACE WAVE MAGNITUDES

In earlier evaluation tasks, the signal amplitude and period values used in computing surface wave magnitudes (M_s) were measured manually on the filtered signal plots at various periods. The computation of M_s then used the equation:

$$M_s = \text{LOG}_{10} \left[\frac{A*SF}{T*Q*G} \right] = \text{LOG}_{10} \Delta + 1.12$$

where:

- A = peak-to-peak amplitude measured in inches on the plot.
- SF = plot scale factor in computer counts per inch.
- T = period in seconds of the measured amplitude.
- Q = quantization factor (20.951 computer counts per millimicron).
- G = instrument response correction factor, and
- Δ = epicentral distance in degrees.

This approach has several disadvantages. First, the analyst is apt to have difficulties finding the largest peak at each desired period - it is sometimes necessary to measure the periods of a number of waveforms before finding the desired period. Next, having found the waveform for which M_g is to be measured, the analyst may make a measurement error. Finally, errors are apt to occur either in transcribing the measured values or in calculating the surface-wave magnitude from these values.

In order to avoid these problems and make the process of obtaining M_g values less tiresome, a program was written to perform the measurements and calculations automatically. This program operates by first finding the times of all zero crossings in a given time gate and the maximum absolute amplitude in millimicrons between each pair of adjacent zero crossings. The waveform period is then simply:

$$T = 2 * [\text{Time of Zero}_{i+1} - \text{Time of Zero}_i] .$$

The program reads the epicentral distance from the event header. The quantization factor and instrument response corrections are built into the program. (The instrument response corrections are derived from the instrument response curve of Figure VI-1.)

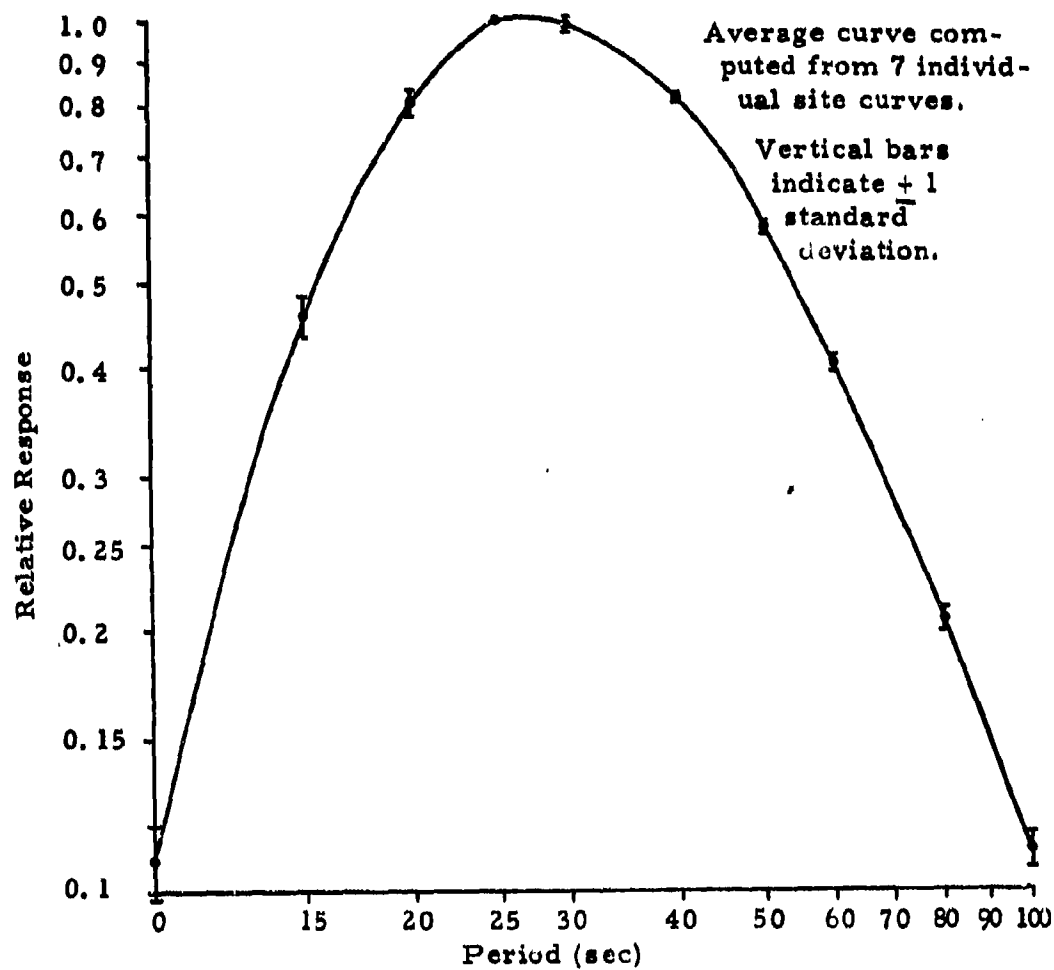


FIGURE VI-1
ILPA INSTRUMENT RESPONSE
NORMALIZED AT 25 SECONDS

The program uses the above information to compute a surface-wave magnitude for each amplitude-period pair. These M_s values with their associated periods and times of measurement are printed out. Finally the program picks the largest M_s value at each specified period of interest and prints it out. The analyst now checks these largest M_s values against the plot of the data. If he does not like an M_s value at a particular period (for example, if the M_s value appears to be associated with a noise pulse in the signal gate) he can select another value from the M_s list generated by the program.

By using this program, measurement errors have been eliminated and transcription errors greatly reduced (since the analyst only writes down the final M_s value and none of the intermediate computational values). Also, the time required to arrive at the M_s values for an event has been reduced.

A further benefit to the evaluation task was found once this program was put into use. Since measurements were no longer being made directly on the plot, it was possible to reduce the length of the plots by one-half. When measurements were made on the plot, a horizontal scale of 100 seconds per inch was considered necessary to minimize measurement errors. Plots are now made with a horizontal scale of 200 seconds per inch. This reduces the amount of plot paper and plot time by one-half and produces more manageable plots.

During the preliminary Iranian Long-Period Array evaluation, M_s was measured at periods of 20, 30, and 40 seconds. However, measurable 40 second energy was not often found - only half as many 40 second M_s values were measured as 20 second or 30 second M_s values. It was also noted that events close to the array have the majority of their energy concentrated at or near 25 seconds period. For these reasons, it has been decided to drop the measurement of 40 second M_s and add the measurement of 25 second M_s .

C. DISCRIMINATION RESULTS

Table VI-1 lists those events of the data base which may be termed presumed nuclear explosions. They were selected on the basis of their epicentral locations and bodywave magnitudes. These events were selected because their epicenters are at or very close to the eastern Kazakh test site and their bodywave magnitudes are larger than most earthquakes from that area.

Figures VI-2 to VI-14 show the M_s - m_b plots for the Iranian Long-Period Array data. The values are plotted for the array with three plots encompassing data from all regions showing surface wave magnitude measured at 20, 25, and 30 seconds, followed by individual plots for 25-second surface wave magnitudes from each region. The symbols used in these plots are:

- O - earthquake with depth less than 60 km or depth unknown.
- + - earthquake with depth greater than 60 km.
- * - presumed nuclear explosion from Region 8.

Such depth information as was available came from the National Earthquake Information Service bulletins. The straight line in each plot represents the equation of the M_s - m_b relationship for that data set. This was computed using the data points for earthquakes with depth less than 60 km or depth unknown. The relationship is computed with a linear fitting algorithm which treats neither variable as dependent. The earthquakes with depths known to be greater than 60 km were excluded from the fitting procedures to avoid biasing the fit. (Deeper events tend to generate relatively lower M_s values.) The slopes and intercepts of the lines fitted to the 20, 25, and 30 second M_s data are given in Table VI-2. The lines fitted to the data of the individual regions are based for the most part on rather sparse populations

TABLE VI-1
LIST OF PRESUMED NUCLEAR EXPLOSIONS

Event Number	m_b	Region	Processing Results
839	4.6	8	Detected
958	5.3	8	Detected
1368	6.0	8	Detected
1549	5.3	8	Not Recorded
1558	5.9	8	Detected
1624	4.9	8	Detected

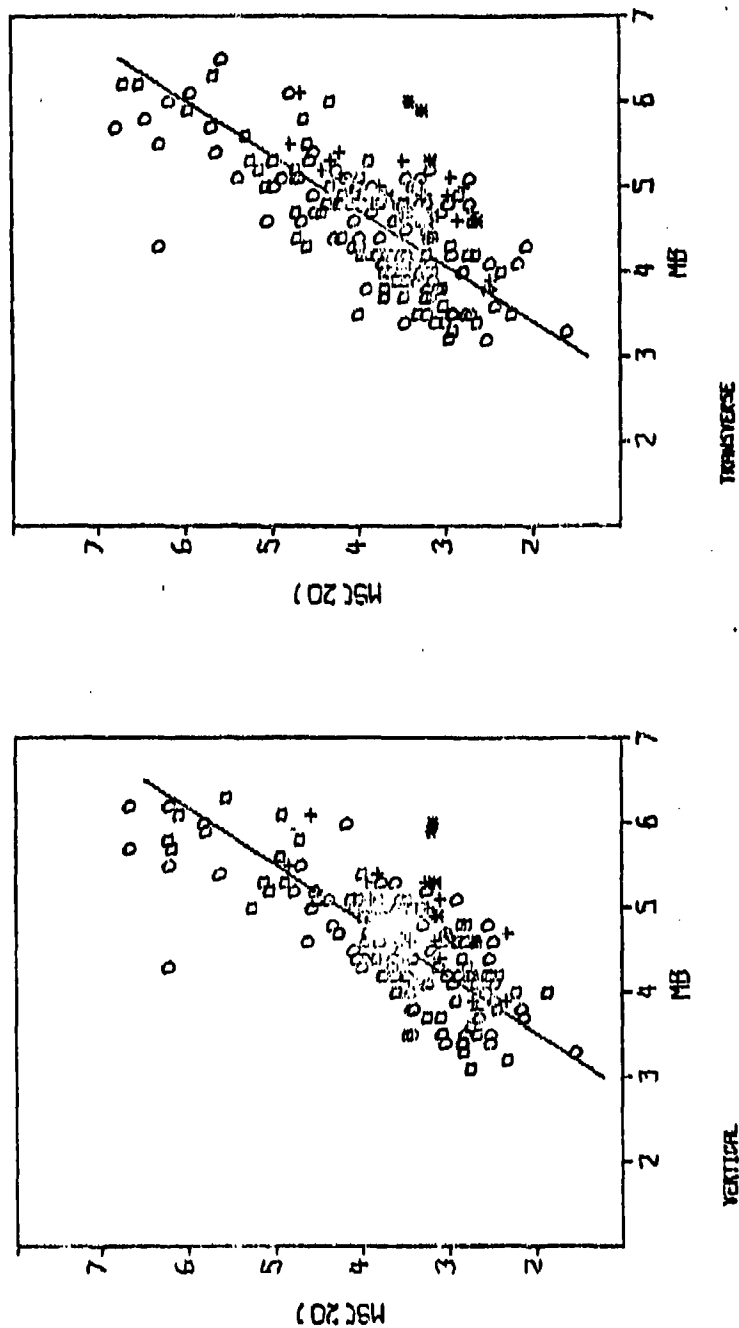


FIGURE VI-2
ILPA $M_s - m_b$ PLOT FOR M_s MEASURED AT 20 SECONDS PERIOD
ALL REGIONS

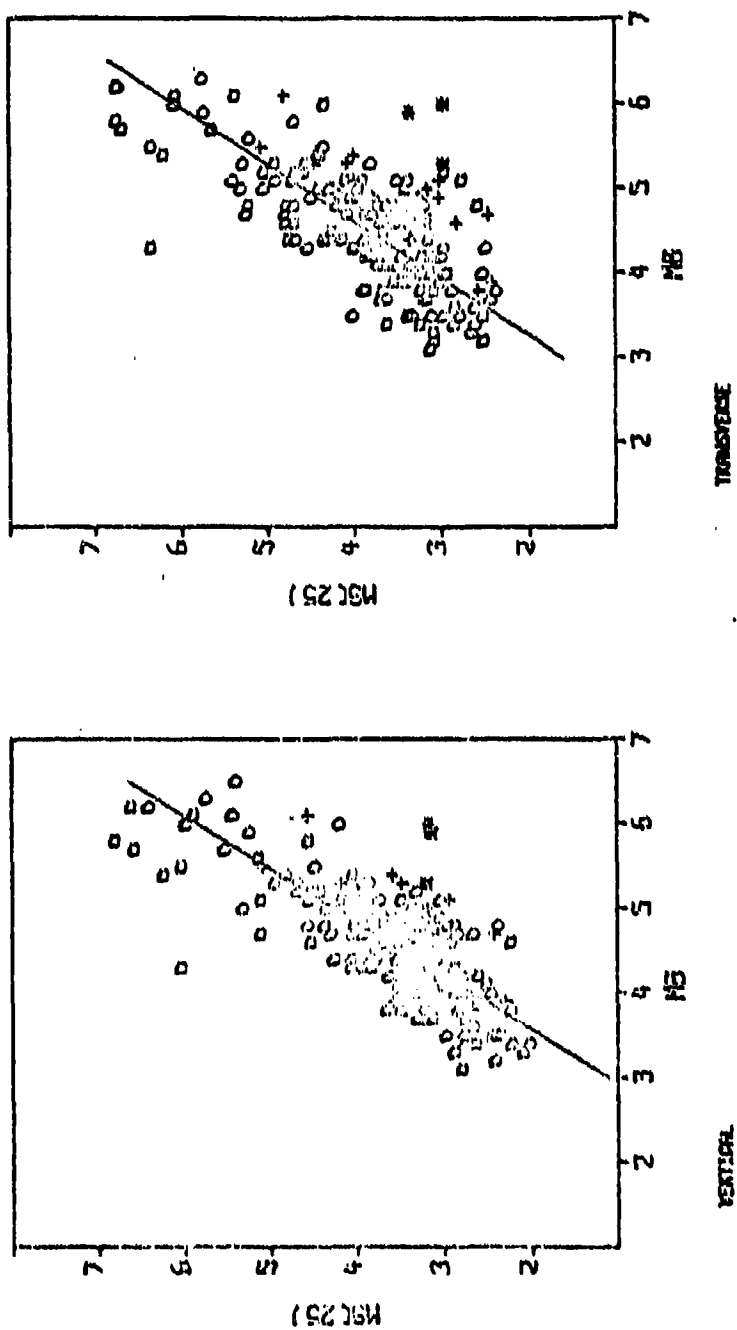


FIGURE VI-3
ILPA $M_s - m_b$ PLOT FOR M MEASURED AT 25 SECONDS PERIOD
ALL REGIONS

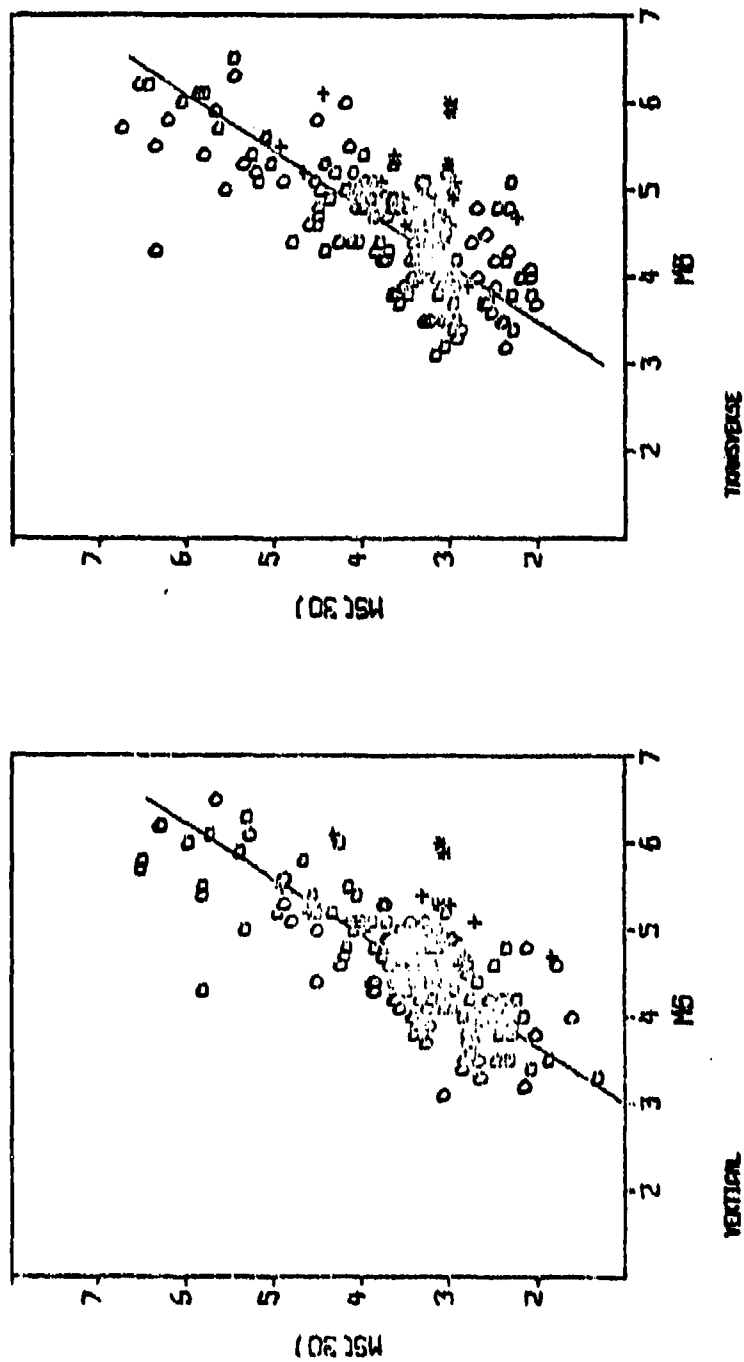


FIGURE VI-4
ILPA $M_s - m_b$ PLOT FOR M_s MEASURED AT 30 SECONDS PERIOD
ALL REGIONS

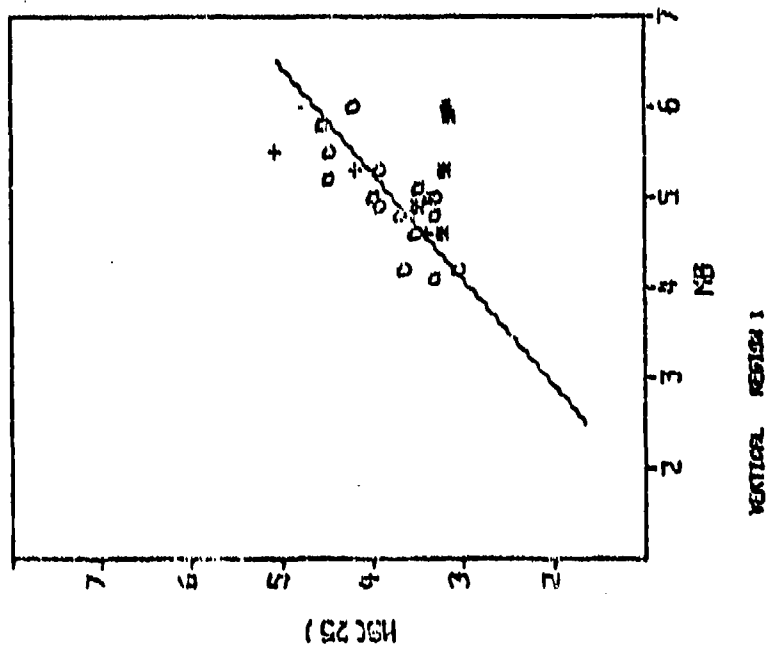
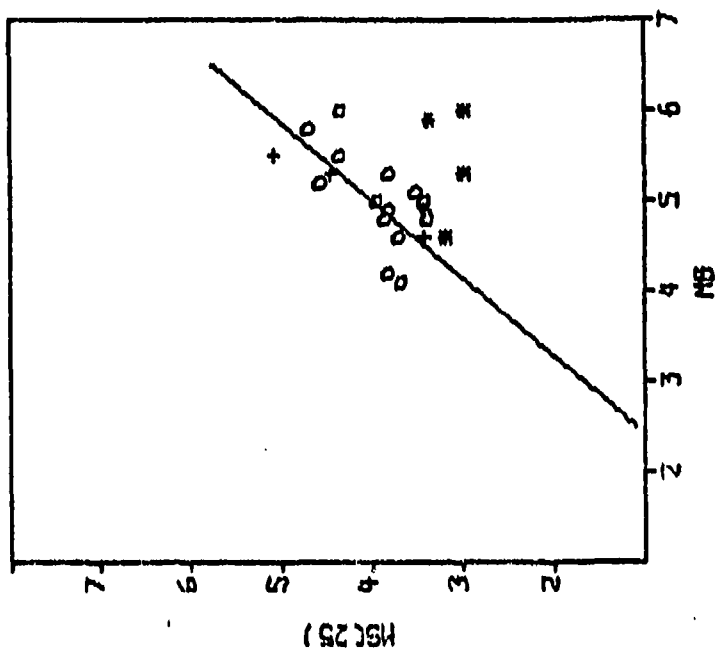


FIGURE VI-5
 $M_s - m_b$ PLOT FOR M_s MEASURED AT 25 SECONDS PERIOD
 REGION 1 EARTHQUAKES

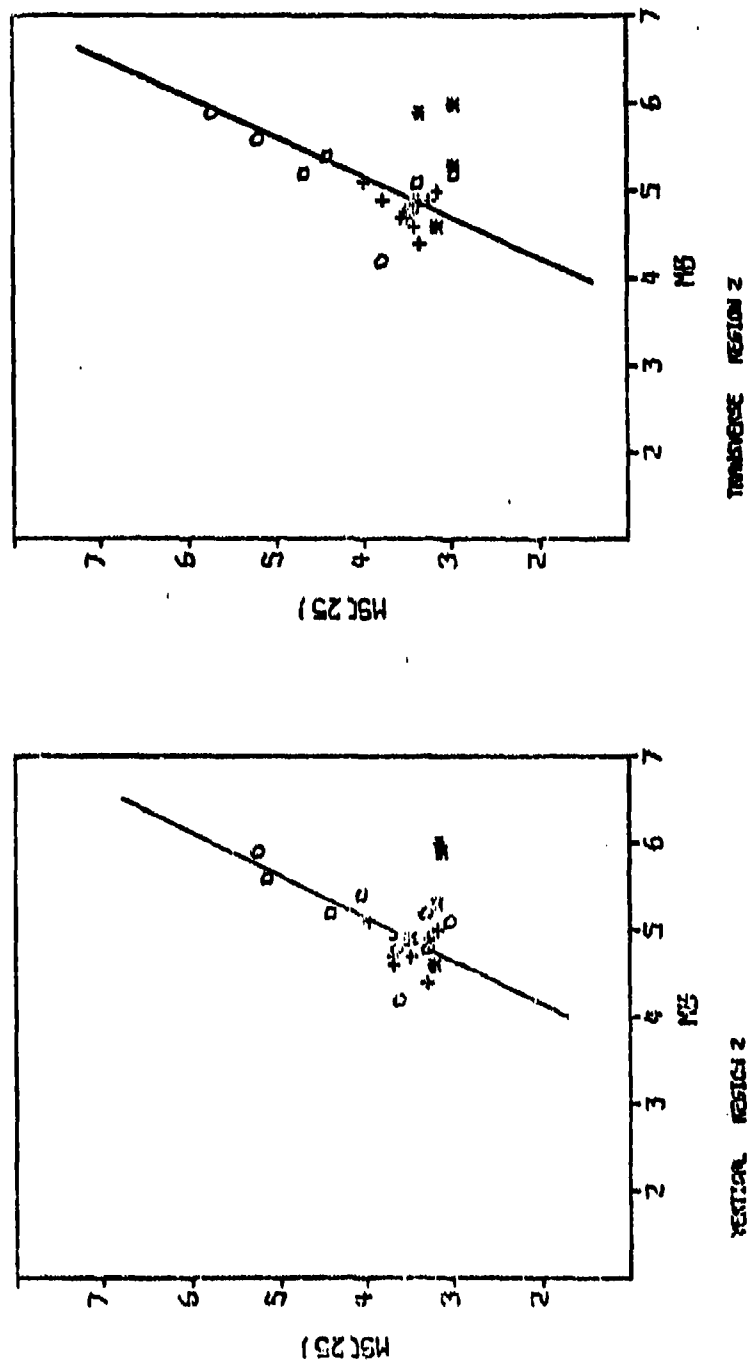


FIGURE VI-6
 ILPA $M_s - m_b$ PLOT FOR M_b MEASURED AT 25 SECONDS PERIOD
 REGION 2 EARTHQUAKES

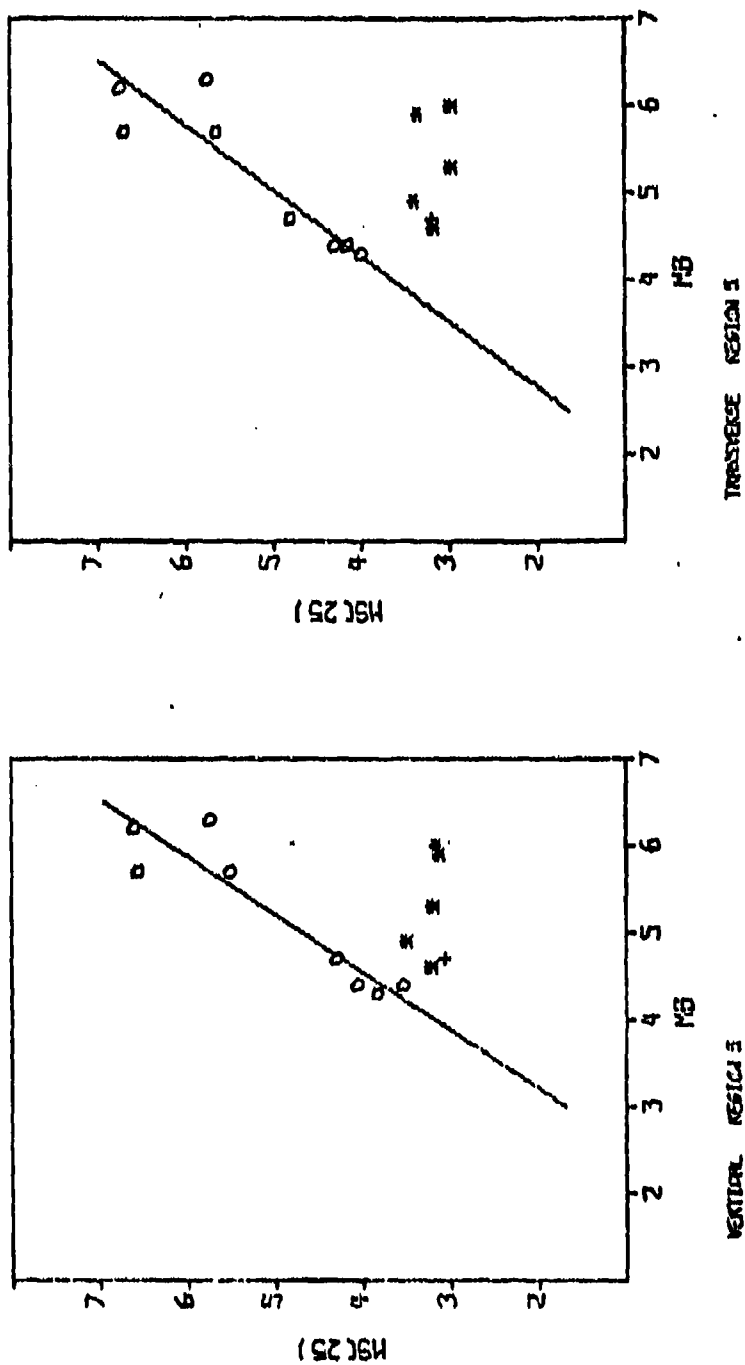


FIGURE VI-7
 ILPA $M_s - m_b$ PLOT FOR M MEASURED AT 25 SECONDS PERIOD
 REGION 5 EARTHQUAKES

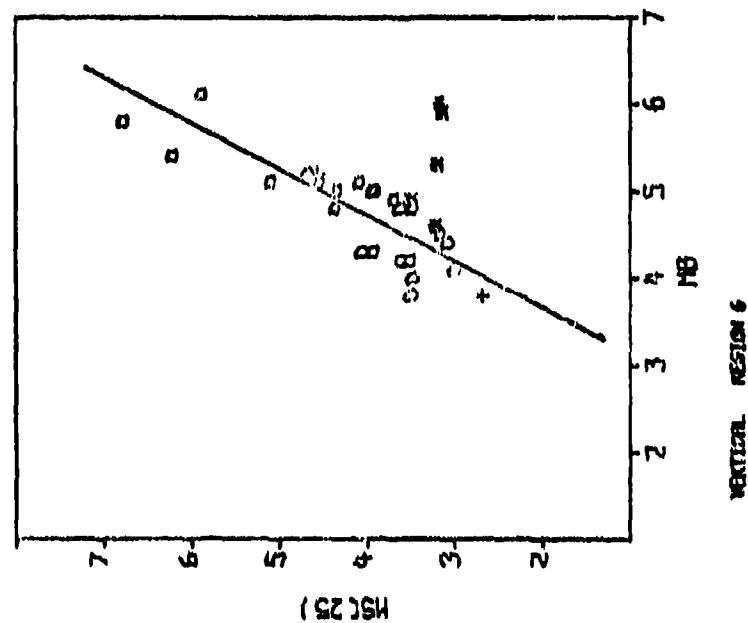
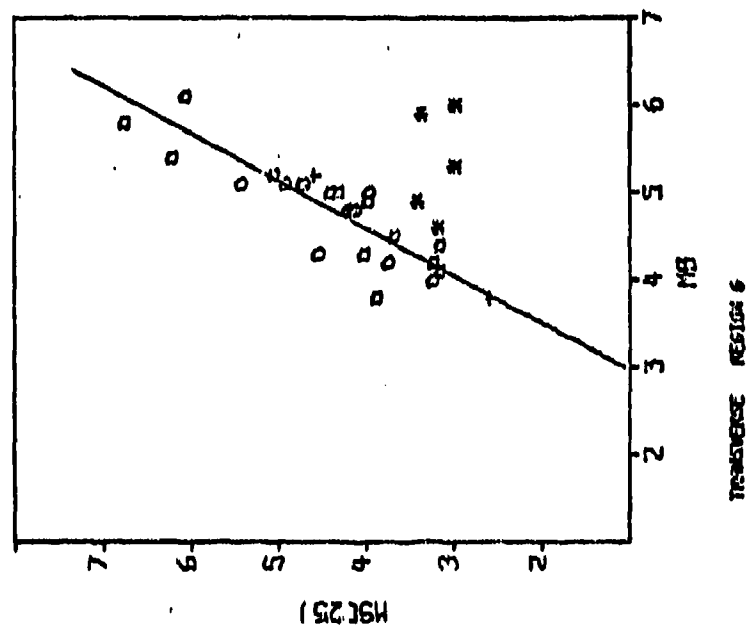


FIGURE VI-8
 ILPA $M_s - m_b$ PLOT FOR M_s MEASURED AT 25 SECONDS PERIOD
 REGION 6 EARTHQUAKES

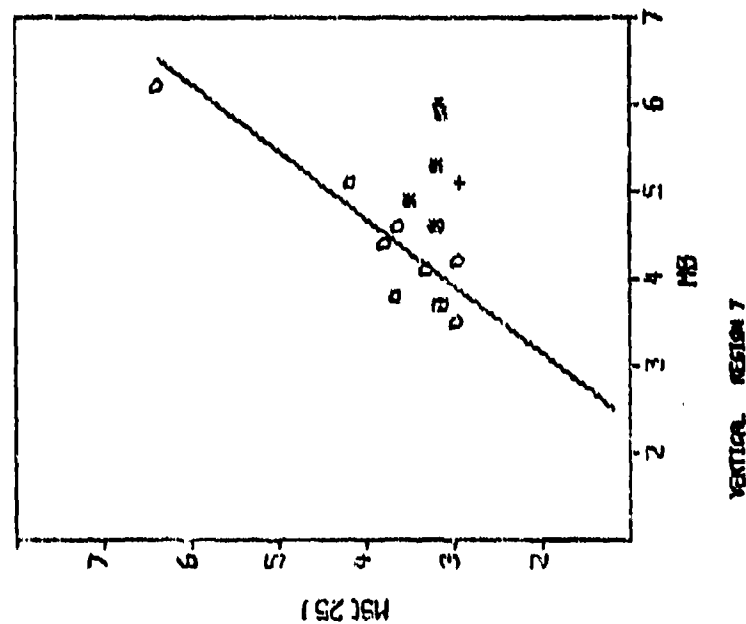
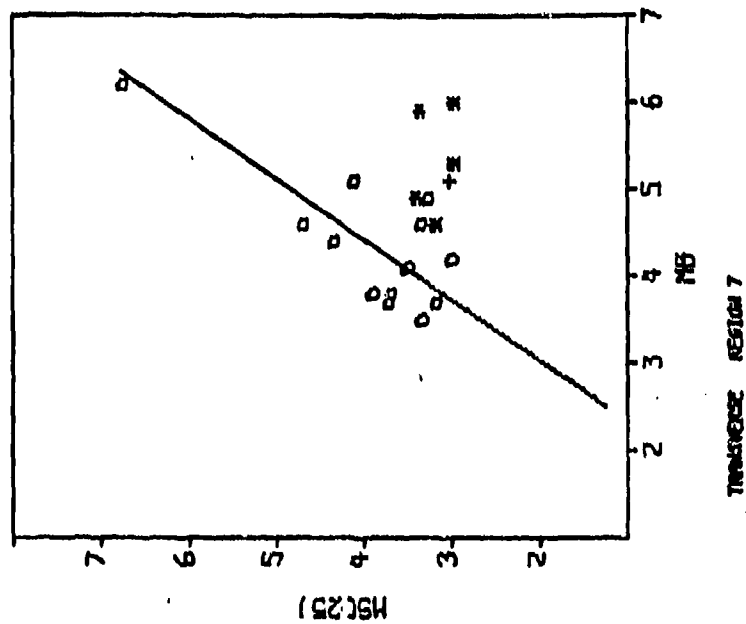


FIGURE VI-9
ILPA M_s - m_b PLOT FOR M_s MEASURED AT 25 SECONDS PERIOD
REGION 7 EARTHQUAKES

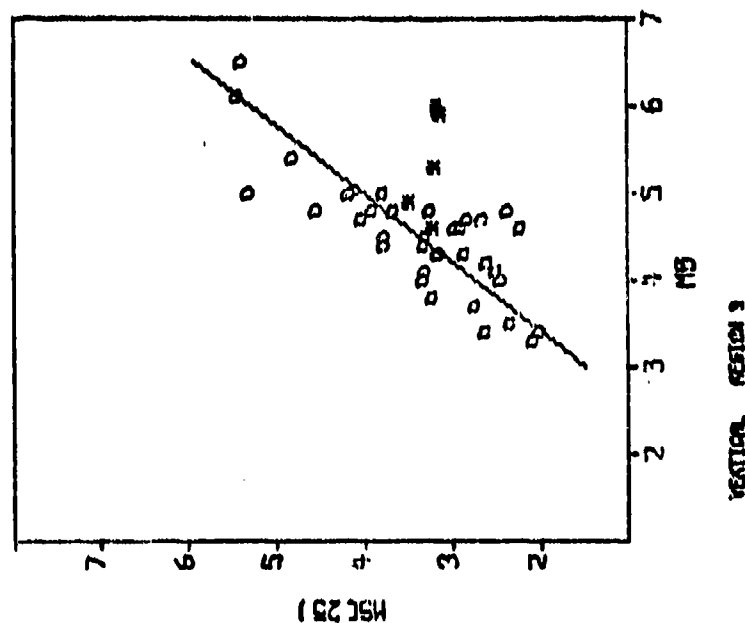
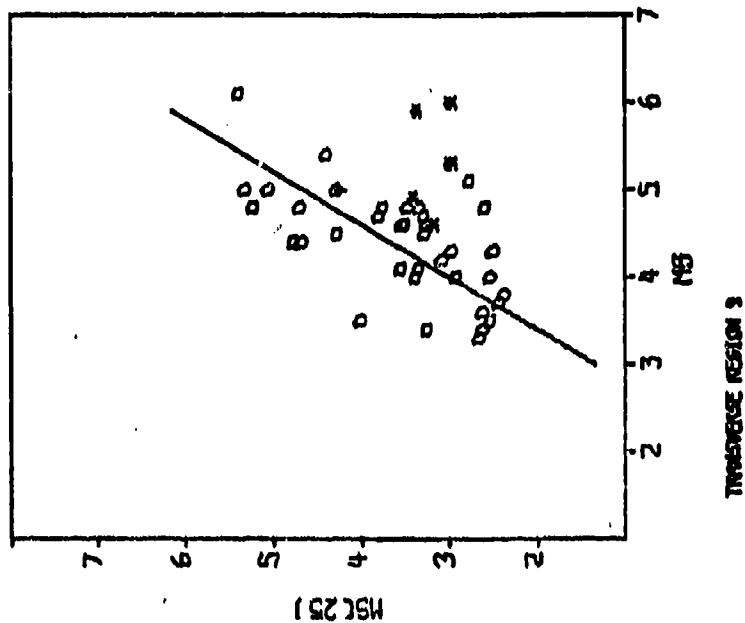


FIGURE VI-10
 ILPA $M_s - m_b$ PLOT FOR M_s MEASURED AT 25 SECONDS PERIOD
 REGION 9 EARTHQUAKES

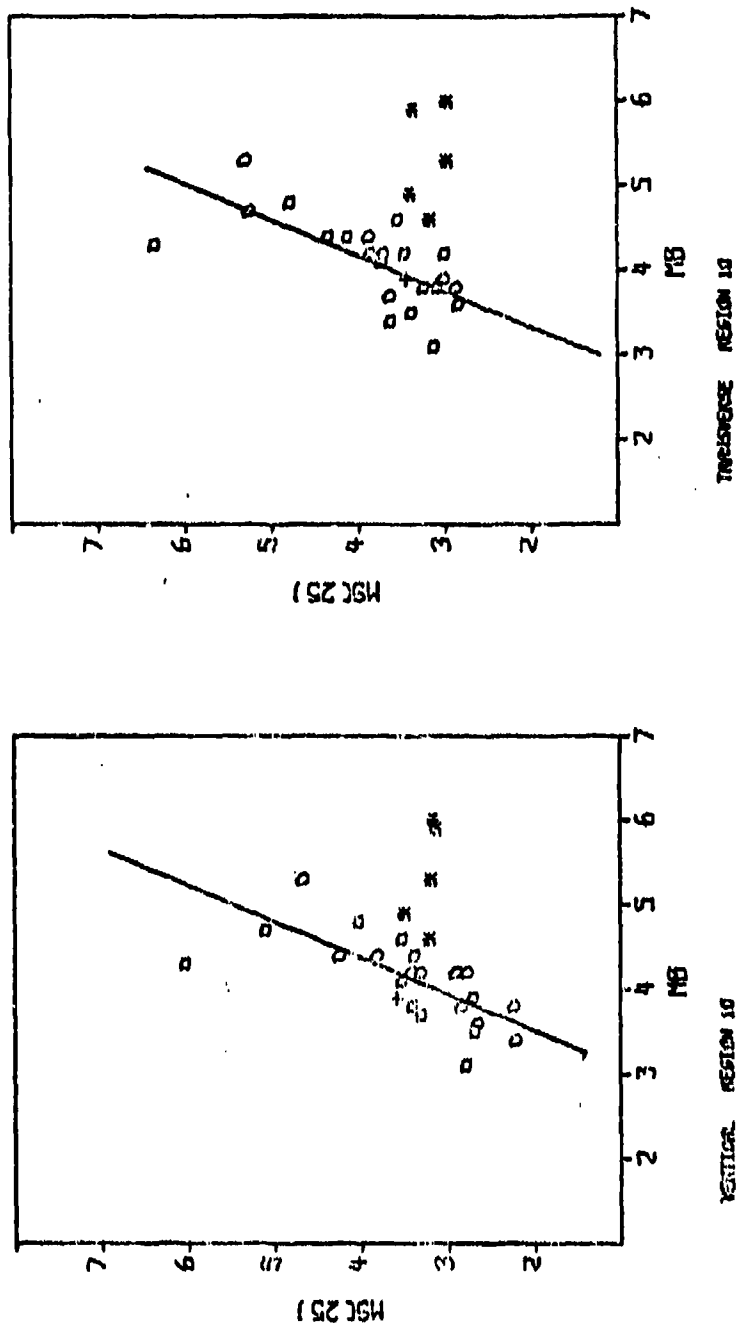


FIGURE VI-11
ILPA $M_s - m_b$ PLOT FOR M_b MEASURED AT 25 SECONDS PERIOD
REGION 10 EARTHQUAKES

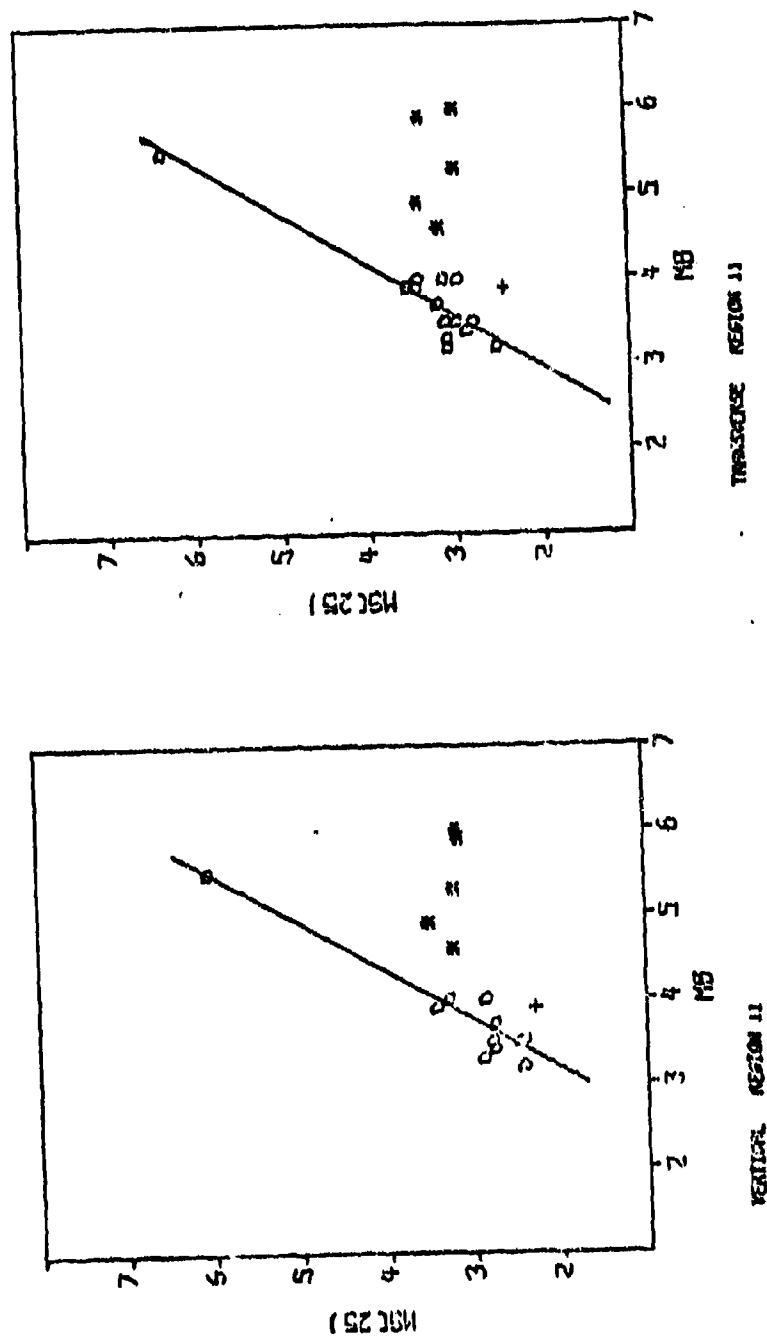


FIGURE VI-12
ILPA $M_s - m_b$ PLOT FOR M_b MEASURED AT 25 SECONDS PERIOD
REGION 11 EARTHQUAKES

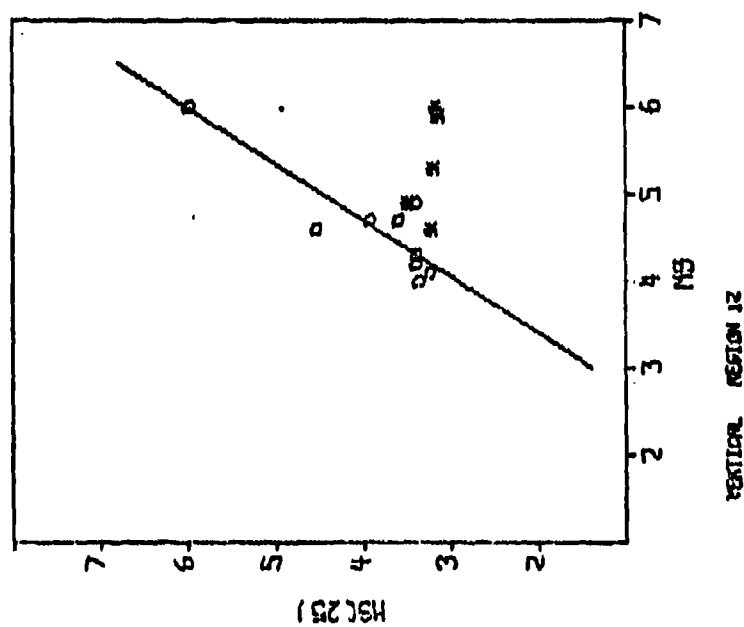
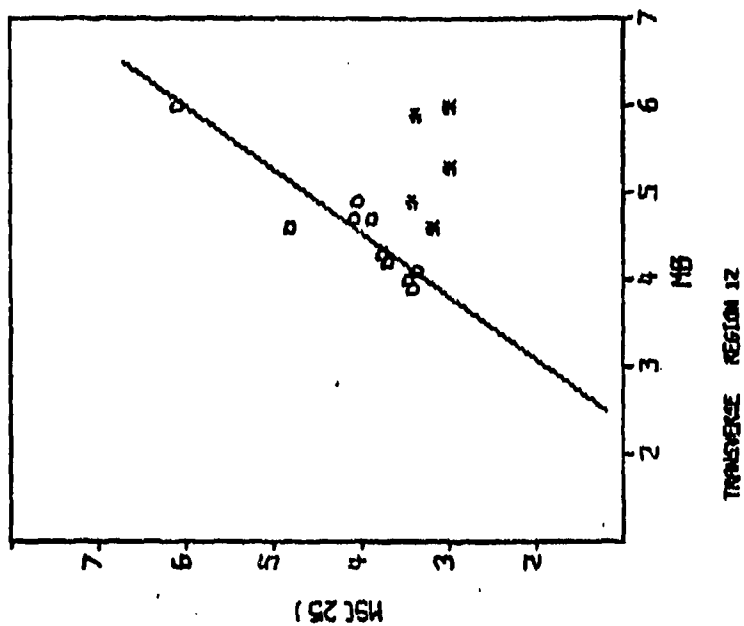


FIGURE VI-13
ILPA $M_s - m_b$ PLOT FOR M_s MEASURED AT 25-SECOND PERIOD
REGION 12 EARTHQUAKES

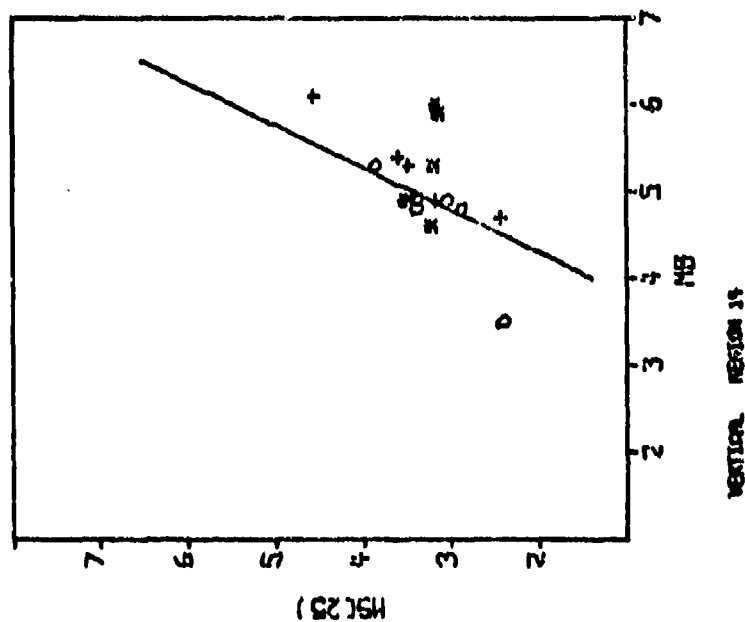
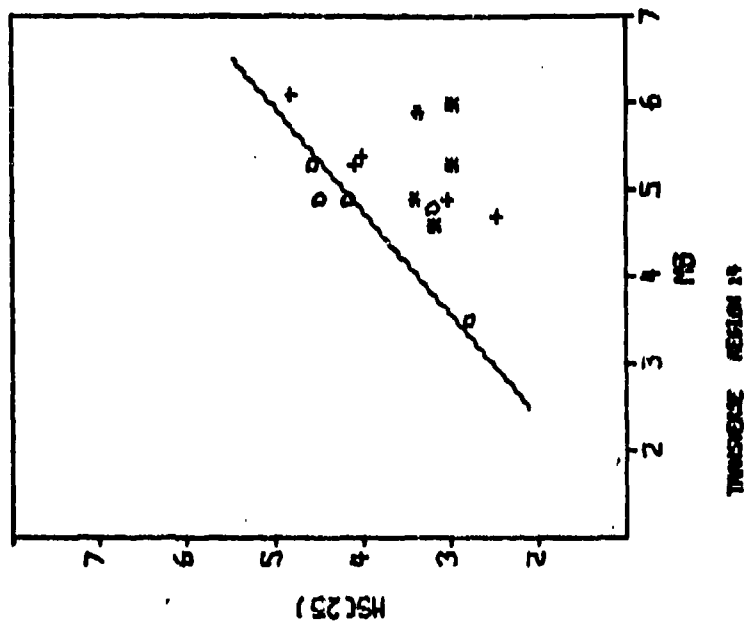


FIGURE VI-14
ILPA $M_s - m_b$ PLOT FOR M_s MEASURED AT 25 SECONDS PERIOD
REGION 14 EARTHQUAKES

TABLE VI-2
 $M_s - m_b$ FIT
 SLOPE AND INTERCEPT VALUES

Period	Component	a	b	σ^2	Center of Mass		
					m_b	M_s	n
20	Vertical	1.51	-3.34	0.20	4.73	3.83	138
	Transverse	1.51	-3.09	0.21	4.64	3.89	152
25	Vertical	1.61	-3.81	0.18	4.71	3.76	147
	Transverse	1.49	-2.92	0.21	4.62	3.97	157
30	Vertical	1.58	-3.80	0.20	4.80	3.78	119
	Transverse	1.56	-3.48	0.23	4.72	3.89	131

where $M_s = am_b + b$

and are intended to be used only as a visual aid in separating earthquakes from presumed nuclear explosions. Little emphasis should be placed on their particular slopes and intercepts.

Considering the individual events of Table VI-1 for which surface wave magnitudes could be measured, the following points should be noted from Figures VI-2 to VI-14:

- Event 839 The surface wave magnitudes for this event fall well within the earthquake population. Therefore, based on this discriminant, this event is classified as an earthquake.
- Event 958 The surface wave magnitudes for this event fall at the lower edge of the earthquake population. Therefore, based on this discriminant, this event cannot be classified as an earthquake or explosion.
- Event 1368 The surface wave magnitudes for this event show excellent separation from the earthquake population. Therefore, based on this discriminant, this event is classified as an explosion.
- Event 1558 The surface wave magnitudes of this event show excellent separation from the earthquake population. Therefore, based on this discriminant, this event is classified as an explosion.
- Event 1624 The surface wave magnitudes for this event fall well within the earthquake population. Therefore, based on this discriminant, this event is classified as an earthquake.

SECTION VII

COMPARISON OF SINGLE-SITE STATION AND ARRAY EVALUATION RESULTS

The goal of this section is to determine the differences in performance between the seven-element Iranian Long-Period Array and a single-site station. The single-site station chosen for this comparison is Mashhad (MAIO) of the Seismic Research Observatory Network, located approximately 700 km from ILPA. This station was selected because it is closest to ILPA of the available single-site stations and has the same sensor system as the individual remote sites of ILPA. All data for MAIO are taken from the current report on the evaluation of the Seismic Research Observatory stations (Strauss, 1977).

If the problems which have shut down ILPA in the past as described in Section II do not recur, the reliability of the array as a whole is assessed as 0.8 (where a reliability factor of 1.0 would be perfect.) At MAIO, this reliability factor is assessed at 0.9. The difference in these reliability estimates can be ascribed to the greater complexity of instrumentation at ILPA, resulting in a higher probability of hardware failure and consequent down-time at the array.

The comparison of mixed event probabilities is presented in Table VII-1. Note that while at MAIO the probability of an event being mixed remains fairly constant for all ranges of bodywave magnitude considered, it tends to drop for increasing bodywave magnitude at ILPA. This difference is due to the process of beamforming array data. If the event causing the mixing is well off the azimuth of the event under analysis and

TABLE VII-1
COMPARISON OF MIXED EVENT PROBABILITIES

m_b Range	P(MIX)	
	MAIO	ILPA Beam
3.1 - 3.5	0.29	0.30
3.6 - 4.0	0.36	0.31
4.1 - 4.5	0.34	0.19
4.6 - 5.0	0.25	0.15

if the amplitudes of the two events as recorded at the array are roughly the same, beamforming will suppress the off-azimuth signal and reveal the signal under analysis. This change from mixed event on single-site to detected event on beam occurred for events processed at the higher values of body-wave magnitude.

Table VII-2 presents the comparison of RMS noise levels measured in the 0.023 - 0.059 Hz passband at MAIO and ILPA. Note first that the RMS noise at MAIO is slightly less than the RMS noise measured at the ILPA reference site. Beamforming the noise recorded at ILPA lowers the ILPA noise levels by 4.7 dB for the vertical component, 3.4 dB for the north component, and 2.0 dB for the east component relative to the MAIO RMS noise levels. For the two highest components, this is an average noise suppression of 4.0 dB relative to MAIO. (This averaging is justified by the consideration that an event is considered to be detected if it is detected on two of the three components and that it is most likely to be detected on the components with highest noise suppression.) From this one can predict that the detection capability of ILPA relative to MAIO (as measured by the 50 percent detection threshold) should be about 0.20 m_b units lower.

Table VII-3 presents the comparison of MAIO and ILPA detection capability. The values of mean epicentral distance ('MEAN DELTA') are presented as an indication that the MAIO and ILPA data bases from which the detection capability estimates were determined had overall essentially the same epicentral distances. Therefore, the comparison is not obscured by differences in detection capability due to differences in epicenter-station separations. The terms 'ALL REGIONS A' and 'ALL REGIONS B' are as previously defined in Section V, where 'ALL REGIONS A' represents the absolute detection capability estimate and 'ALL REGIONS B' represents the conditional detection capability estimate.

TABLE VII-2
COMPARISON OF RMS NOISE LEVELS
(ALL VALUES IN $m\mu$)

Station	Vertical		North		East	
	Mean	S. D. *	Mean	S. D. *	Mean	S. D. *
MAIO	8.20	4.37	7.89	3.45	8.19	4.00
ILPA Reference Site	9.58	2.19	9.34	2.56	9.86	2.98
ILPA BEAM	4.77	1.44	5.36	1.82	6.51	2.31

* S. D. = Standard Deviation

Note: RMS noise computed in 0.023 - 0.059 Hz passband
(no correction for instrument response)

TABLE VII-3
COMPARISON OF ILPA AND MAIO DETECTION CAPABILITY

Type of Detection Statistics	MAIO		ILPA	
	m_{b50}	Mean Delta (degrees)	m_{b50}	Mean Delta (degrees)
All Regions A	4.55	38.5	4.42	36.5
All Regions B	4.13		3.94	

The data of Table VII-3 show that the ILPA detection capability is affected slightly more than the MAIO detection capability by the aggregate of mixed events, malfunctions, and system failures causing no data to be recorded. (Note that ILPA is evaluated only for those times when it was nominally operational.) For ILPA, the absolute and conditional detection capability estimates differ by 0.48 m_b units, while for MAIO the difference is 0.42 m_b units. Considering the mixed event probabilities of Table VII-1, this difference must be a direct result of the lower reliability of ILPA.

A value of 0.20 m_b units was predicted from the relative ILPA and MAIO RMS noise levels as the improvement in the ILPA detection capability relative to the MAIO detection capability. Since this does not take into account the effects of mixed events, malfunctions, and system failures resulting in no data being recorded, it represents an improvement in the conditional detection capability estimates. From Table VII-3, the ILPA conditional detection capability estimate ('ALL REGIONS B') is 0.19 m_b units lower than that of MAIO, which agrees quite well with the predicted improvement.

SECTION VIII

CONCLUSIONS

This section summarizes the results of the continued evaluation of the Iranian Long-Period Array (ILPA) and presents plans for necessary future work. The major conclusions are:

A. DATA QUALITY

- In general, the data quality is fairly good. Of 680 events examined, 6.6% were lost due to unreadable data, 6.2% were lost due to gaps in the recorded data, and 4.1% were lost due to uncorrectable system malfunctions.
- Estimates of array reliability were based on estimates of array up time, frequency of occurrence of recorded and readable data, and frequency of occurrence of system malfunctions. The worst case estimate of ILPA reliability is 0.54 and the best case estimate is 0.79.
- The probability of an event being mixed was estimated at approximately 0.25 for a range of m_b values from 3.1 to 5.0.

B. NOISE ANALYSIS

- RMS noise amplitudes do not vary greatly from site to site.
- Noise suppression due to beamforming is greater on the vertical component than on either of the horizontal components.
- For all sites except site 1, the RMS noise amplitudes for periods above 25 seconds are higher on the horizontal components than on the vertical component.

- At periods above 25 seconds, beamforming lowers the vertical component RMS amplitude spectrum much more than the horizontal spectra.
- The above points indicate that use of a 0.033 - 0.050 Hz passband filter in place of the 0.023 - 0.059 Hz passband filter previously used may significantly enhance the signal-to-noise ratio of the ILPA data.
- Multichannel noise coherencies for the 7-element ILPA array are quite similar in level as a function of frequency to those determined from the inner-ring sites of the Norwegian Seismic Array.
- The level of multichannel coherence in the 0.023-0.059 Hz filter passband is high enough that multichannel filtering may be effective.
- There is very little 0.01172 Hz propagating noise arriving at ILPA.
- The majority of 0.04297 Hz and 0.05859 Hz propagating noise with signal phase velocities have arrival azimuths directed toward the south, away from the general seismic area of interest.

C. SIGNAL ANALYSIS

- The highest gain in signal-to-noise ratio due to beamforming was 6.9 dB on the vertical component. Gains on the transverse and radial components were 4.4 and 4.0 dB, respectively.
- The LQ-transverse component yielded larger correlation coefficients than either the LR-vertical or LR-radial components.

The LR-radial component produced the lowest correlation coefficients on average. Sites 3 and 6 gave the highest correlation coefficients, while site 4 yielded the lowest correlation coefficients.

D. DETECTION CAPABILITY

- The absolute 50 percent detection capability estimate for ILPA beam data using NORSAR m_b values is at $m_b = 4.42$ for Eurasian events. The absolute detection capability estimate was computed by including all mixed events, events for which no data were available and events containing malfunctions as non-detections.
- The conditional 50 percent detection capability estimate for ILPA beam data using NORSAR m_b values is at $m_b = 3.94$ for Eurasian events. The conditional detection capability estimate was computed by excluding all mixed events, events for which no data were available and events containing malfunctions from the detection statistics.
- Mixed events, events for which no data were available and malfunctions raised the 50 percent detection threshold for the reference site and beam by 0.41 and 0.48 m_b units, respectively.

E. DISCRIMINATION

- Events 839 and 1624 show surface wave magnitudes indicating that they are earthquakes.
- Event 958 could not be classified as either earthquake or explosion.
- Events 1368 and 1558 show surface wave magnitudes indicating that they are nuclear explosions.

F. COMPARISON WITH A SINGLE-SITE STATION

- ILPA reliability is estimated at 0.8, in comparison with 0.9 at MAIO. This reflects the greater system complexity of ILPA.
- Due to the beamforming process, the probability of an event being mixed decreases with increasing bodywave magnitude at ILPA while remaining fairly constant at MAIO.
- While the RMS noise levels at ILPA are slightly greater than those at MAIO, beamforming produces an average noise suppression of 4.0 dB at ILPA relative to MAIO.
- The conditional detection capability estimate at ILPA is approximately 0.2 m_b units lower than that of MAIO.

G. FUTURE WORK

The following items should be investigated to complete the evaluation of the Iranian Long-Period Array:

- Investigate the long-period noise field in more detail. Points covered should include RMS noise levels in different passbands, reasons for increased horizontal component noise at periods beyond 30 seconds, and frequency-wavenumber spectra for more noise samples to better define source azimuths of propagating noise.
- Refine regionalized detection capability estimates. This will require processing and analyzing approximately 500 more events.
- Process more presumed nuclear explosions to better estimate the ILPA discrimination capability.

- Process a suite of detected and non-detected events with the 0.033 - 0.050 Hz passband to determine the effect of removing the elevated noise levels beyond 30 seconds on detection capability.
- Completely evaluate the single recorded component of short-period data in terms of noise characteristics, detection capability, and discrimination capability.

SECTION IX
REFERENCES

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- Strauss, A. C., 1976, Preliminary Evaluation of the Iranian Long-Period Array; Technical Report Number 1, ALEX(01)-TR-76-01, AFTAC Contract Number F08606-76-C-0011, Texas Instruments Incorporated, Dallas, Texas.
- Strauss, A. C., 1977, Continuation of the Seismic Research Observatories Evaluation; Technical Report Number 2, ALEX(01)-TR-77-02, AFTAC Contract Number F08606-77-C-0004, Texas Instruments Incorporated, Dallas, Texas.
- Texas Instruments, 1977, Iranian Long-Period Array Final Report; Contract Number 14-08-0001-14031, Texas Instruments Incorporated, Dallas, Texas.

APPENDIX A THE DATA BASE

This appendix presents the parameters describing each event in the data base. The column headed 'EVNO' gives the number assigned to each event. (These event numbers are the same as those used in the Seismic Research Observatory evaluation.) The column headed 'DATE' gives the month, day, and year of occurrence of the event. The column headed 'TIME' gives the origin time of the event. The columns headed 'LAT.' and 'LONG.' give the latitude and longitude of the event epicenter, where a positive value indicates north latitude or east longitude (as appropriate) and a negative value indicates south latitude or west longitude. The column headed 'MB' gives the body-wave magnitude of the event. The column headed 'Q' gives the NORSAR quality rating of the event parameters, where

1 = good to excellent

2 = fair to good

3 = poor to fair.

A zero in this column indicates the event parameters came from the NEIS event bulletin. The column headed 'LOCATION' gives the general area in which the event occurred. Finally, the column headed 'SUBREG' gives the sub-region number of the event as defined by Flinn and Engdahl (Flinn and Engdahl, 1965).

TABLE A-1
DATA BASE
(PAGE 1 OF 16)

EWNC	DATE	TIME	LAT.	LONG.	HB	Q	LOCATION	SUBREG
715	5/1/76	8:28:59	34.0	80.0	3.7	3	TIBET	306
716	5/1/76	11:30:33	32.0	89.0	4.3	3	S. SINKIANG PROV.	321
717	5/1/76	16:30:10	32.0	62.0	3.8	1	SW AFGHANISTAN	350
718	5/1/76	19:34:12	41.0	142.0	4.9	1	NEC HONSHU, JAPAN	228
719	5/2/76	0:25:29	35.0	27.0	3.5	3	CRETE	370
720	5/2/76	15:20:25	50.0	155.0	4.1	2	KURILE ISLANDS	221
721	5/2/76	15:41:30	39.0	158.0	3.6	3	UZBEK SSR	339
722	5/2/76	15:37:30	53.0	158.0	3.7	3	NEC KAMCHATKA	218
723	5/2/76	16:57:26	30.0	51.0	4.1	2	IRAN	348
724	5/3/76	11:3:29	40.0	76.0	3.7	2	KIRGIZ-SINKIANG BDR.	320
725	5/4/76	3:29:39	47.0	158.0	4.2	1	KURILE ISLANDS	221
726	5/4/76	5:23:59	32.0	90.0	3.5	2	WESTERN IRAN	347
727	5/4/76	6:1:51	26.0	98.0	4.3	2	TIBET	306
728	5/4/76	7:5:11	27.0	87.0	3.8	3	NORTHERN INDIA	308
729	5/5/76	10:2:36	42.0	141.0	3.8	3	HOKKAIDO, JAPAN REG.	224
730	5/5/76	13:26:18	45.0	149.0	4.5	1	KURILE ISLANDS	221
731	5/5/76	16:12:25	44.0	146.0	4.2	3	HOKKAIDO, JAPAN REG.	224
732	5/5/76	18:21:35	31.0	177.0	4.2	2	NORTHERN INDIA	308
733	5/5/76	11:13:20	48.0	149.0	4.4	2	KURILE ISLANDS	221
734	5/5/76	16:53:20	43.0	150.0	4.2	2	KIRGIZ-SINKIANG BDR.	320
735	5/6/76	17:42:43	44.0	147.0	4.7	1	KURILE ISLANDS	221
736	5/6/76	17:59:47	35.0	24.0	4.7	2	CRETE	370
737	5/6/76	20:36:47	39.0	64.0	4.5	2	UZBEK SSR	339
738	5/7/76	2:10:54	43.0	140.0	4.5	2	UZBEK SSR	339
739	5/7/76	4:34:20	48.0	154.0	4.8	2	HOKKAIDO, JAPAN REG.	224
740	5/7/76	8:2:53	32.0	78.0	3.8	3	KURILE ISLANDS	221
741	5/7/76	18:2:53	40.0	29.0	3.8	3	KASHMIR-TIBET BDR.	304
742	5/8/76	2:55:34	40.0	30.0	3.8	3	TURKEY	366
743	5/8/76	5:53:4	36.0	22.0	3.6	3	MEDITERRANEAN SEA	400
744	5/8/76	7:51:25	41.0	63.0	5.5	2	UZBEK SSR	339
745	5/8/76	8:12:47	45.0	149.0	5.5	3	KURILE ISLANDS	221
746	5/8/76	11:19:27	40.0	140.0	4.4	2	TURKEY	366
747	5/8/76	13:14:27	40.0	140.0	4.4	2	NEC HONSHU, JAPAN	228
748	5/8/76	15:1:25	40.0	140.0	4.4	2	TURKEY	366
749	5/9/76	16:30:25	46.0	150.0	3.6	3	KURILE ISLANDS	221
750	5/9/76	20:11:8	40.0	130.0	3.3	2	TURKEY	366
751	5/9/76	22:35:31	46.0	35.0	3.5	3	CRIMEA REGION	361
752	5/10/76	4:34:56	39.0	19.0	3.3	2	GREECE-ALBANIA BDR.	392
753	5/10/76	8:14:56	39.0	15.0	3.3	2	SICILY	398

TABLE A-1
DATA BASE
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PWNO	DATE	TIME	LAT.	LONG.	HB	Q	LOCATION	SUBREG
755	5/10/76	12:13:38	40.0	29.0	4.2	3	TURKEY	356
756	5/10/76	15:20:49	39.0	30.0	4.2	3	TURKEY	366
757	5/10/76	18:37:24	29.0	82.0	4.0	3	NEPAL	310
758	5/10/76	18:43:40	29.0	83.0	4.2	3	NEPAL-INDIA BOR.	309
759	5/10/76	23:34:15	46.0	36.0	5.0	3	SOUTHWESTERN RUSSIA	357
760	5/10/76	23:54:14	40.0	30.0	4.0	3	TURKEY	366
761	5/11/76	3:22:08	30.0	81.0	3.4	3	NEPAL	310
762	5/11/76	4:32:16	40.0	30.0	4.1	3	TURKEY	366
763	5/11/76	7:14:13	33.0	141.0	4.1	3	NEC HONSHU, JAPAN	228
764	5/11/76	13:26:51	45.0	149.0	3.8	3	IRAN	348
765	5/11/76	17:00:23	41.0	221.0	5.2	2	KURILE ISLANDS	221
766	5/11/76	17:09:55	36.0	222.0	5.3	3	GREECE-ALBANIA BOR.	392
767	5/11/76	19:25:00	32.0	49.0	4.0	3	MEDITERRANEAN SEA	400
768	5/11/76	21:11:51	35.0	22.0	4.0	3	WESTERN IRAN	347
769	5/12/76	5:11:49	40.0	30.0	4.0	3	MEDITERRANEAN SEA	400
770	5/12/76	5:26:16	38.0	21.0	3.2	3	TURKEY	366
771	5/12/76	16:45:40	52.0	160.0	4.1	3	IONIAN SEA	399
772	5/12/76	18:40:25	42.0	185.0	4.2	2	IOCEAN KANCHAIKA	3219
773	5/12/76	3:44:48	43.0	20.0	4.0	3	IOCEAN SEA	399
774	5/13/76	9:50:18	36.0	140.0	3.3	3	IOCEAN SEA	225
775	5/13/76	11:00:29	30.0	30.0	4.0	3	YUGOSLAVIA	383
776	5/13/76	13:18:34	36.0	22.0	3.5	3	KURILE ISLANDS	221
777	5/13/76	19:23:46	38.0	21.0	4.0	3	HONSHU, JAPAN	227
778	5/13/76	20:44:32	35.0	21.0	4.0	3	TURKEY	366
779	5/13/76	22:17:48	36.0	22.0	3.5	3	MEDITERRANEAN SEA	400
780	5/13/76	23:17:21	40.0	143.0	2.5	3	IONIAN SEA	399
781	5/13/76	1:23:17	38.0	30.0	4.0	3	NEC HONSHU, JAPAN	228
782	5/13/76	15:13:30	43.0	149.0	3.3	3	CRETE	366
783	5/13/76	20:24:53	39.0	142.0	4.2	3	IONIAN SEA	222
784	5/13/76	23:17:21	40.0	143.0	3.3	3	MEDITERRANEAN SEA	228
785	5/13/76	23:17:21	40.0	143.0	3.3	3	NEC HONSHU, JAPAN	228
786	5/13/76	23:17:21	40.0	143.0	3.3	3	TURKEY	366
787	5/13/76	23:17:21	40.0	143.0	3.3	3	KURILE ISLANDS RES.	222
788	5/13/76	23:17:21	40.0	143.0	3.3	3	NEC HONSHU, JAPAN	228
789	5/13/76	23:17:21	40.0	143.0	3.3	3	HOKKAIDO, JAPAN	228
790	5/13/76	23:17:21	40.0	143.0	3.3	3	NEC HONSHU, JAPAN	228
791	5/13/76	23:17:21	40.0	143.0	3.3	3	CRETE	370
792	5/13/76	23:17:21	40.0	143.0	3.3	3	NEC HONSHU, JAPAN	370
793	5/13/76	23:17:21	40.0	143.0	3.3	3	CRETE	370
794	5/13/76	23:17:21	40.0	143.0	3.3	3	BURMA-INDIA BOR.	294

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TABLE A-1
DATA BASE
(PAGE 3 OF 16)

SVNO	DATE	TIME	LAT.	LONG.	MB	Q	LOCATION	SUBREG
705	5/15/76	8:11:59	19.0	95.0	4.8	1	BURMA	296
706	5/15/76	11:16:28	40.0	30.0	4.4	2	TURKEY	366
707	5/15/76	19:12:29	42.0	21.0	2.8	3	IONIAN SEA	399
709	5/15/76	23:5:23	38.0	144.0	3.9	3	HOKKAIDO, JAPAN	224
							OC HONSHU, JAPAN	229
800	5/16/76	8:1:16	36.0	51.0	7.5	2	IRAN	348
801	5/16/76	15:40:16	36.0	74.0	3.5	2	NORTHWESTERN KASHMIR	720
802	5/16/76	26:25:16	48.0	154.0	4.2	2	KURILE ISLANDS	221
803	5/17/76	3:21:30	39.0	54.0	6.5	1	UZBEK SSR	339
804	5/17/76	3:21:30	39.0	64.0	4.4	2	UZBEK SSR	339
805	5/17/76	3:29:14	39.0	64.0	4.4	2	UZBEK SSR	339
806	5/17/76	3:57:26	41.0	62.0	4.1	2	TURKMEEN SSR	340
807	5/17/76	4:14:33	42.0	52.0	4.5	2	UZBEK SSR	339
808	5/17/76	4:34:15	39.0	65.0	3.4	2	TURKMEEN SSR	340
809	5/17/76	4:34:15	42.0	61.0	4.7	2	TURKMEEN SSR	340
810	5/17/76	5:53:10	39.0	64.0	4.0	2	UZBEK SSR	339
811	5/17/76	6:37:28	39.0	54.0	3.3	2	TURKMEEN SSR	339
812	5/17/76	6:37:11	39.0	61.0	3.3	2	UZBEK SSR	339
813	5/17/76	6:58:11	41.0	64.0	3.6	2	UZBEK SSR	339
814	5/17/76	7:20:3	39.0	63.0	3.3	2	UZBEK SSR	339
815	5/17/76	8:10:26	39.0	54.0	3.3	2	TURKMEEN SSR	340
816	5/17/76	10:44:12	41.0	63.0	4.0	2	UZBEK SSR	339
817	5/17/76	11:39:36	41.0	62.0	4.0	2	UZBEK SSR	339
818	5/17/76	15:11:36	38.0	21.0	3.7	3	TURKEY	366
819	5/17/76	16:11:36	38.0	21.0	3.7	3	IONIAN SEA	339
820	5/17/76	16:38:10	41.0	63.0	3.7	3	UZBEK SSR	339
821	5/17/76	17:46:18	40.0	64.0	3.5	3	UZBEK SSR	339
822	5/17/76	20:18:28	42.0	62.0	4.3	2	UZBEK SSR	339
823	5/17/76	21:52:25	41.0	52.0	3.8	2	UZBEK SSR	339
824	5/17/76	22:18:25	56.0	162.0	4.8	1	NEC KAHCHATKA	218
825	5/18/76	5:35:37	43.0	61.0	4.3	3	UZBEK SSR	339
826	5/18/76	7:59:41	35.0	27.0	4.2	3	CRETE	370
827	5/18/76	8:30:14	35.0	27.0	4.2	3	CRETE	370
828	5/18/76	8:54:32	41.0	62.0	4.8	1	UZBEK SSR	339
829	5/18/76	13:54:32	41.0	62.0	4.8	1	TURKMEEN SSR	340
830	5/18/76	16:15:50	38.0	21.0	3.8	3	IONIAN SEA	399
831	5/18/76	17:17:51	38.0	21.0	3.8	3	IONIAN SEA	399
832	5/18/76	20:11:39	39.0	64.0	7.6	2	TURKMEEN SSR	340
833	5/18/76	20:22:29	39.0	64.0	3.3	2	UZBEK SSR	339
834	5/18/76	20:24:29	39.0	145.0	3.3	3	OC HONSHU, JAPAN	229

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TABLE A-1

DATA BASE

(PAGE 4 OF 16)

EVNO	DATE	TIME	LAT.	LONG.	MB	Q	LOCATION	SUBREG
835	5/18/76	22:48:47	39:00	64:00	3:4	2	TURKMEN SSR	340
836	5/18/76	23:00:00	36:00	62:00	3:5	1	MEDITERRANEAN SEA	400
837	5/19/76	23:11:12	39:00	62:00	4:2	1	UZBEK SSR	339
838	5/19/76	2:26:46	41:00	63:00	3:5	1	UZBEK SSR	339
839	5/19/76	2:56:46	49:00	80:00	4:6	1	PASTERN KAZAKH SSR	329
840	5/19/76	7:30:16	39:00	65:00	3:6	1	TURKMEN SSR	340
841	5/19/76	15:54:58	41:00	62:00	4:0	1	TURKMEN SSR	340
842	5/19/76	16:44:33	38:00	21:00	3:0	2	IONIAN SEA	349
843	5/20/76	16:44:33	33:00	55:00	3:9	2	IRAN	348
844	5/20/76	11:37:15	33:00	54:00	3:3	2	UZBEK SSR	339
845	5/20/76	19:42:40	46:00	152:00	4:0	2	KURILE ISLANDS	221
846	5/20/76	22:44:24	45:00	149:00	3:7	3	KURILE ISLANDS	221
847	5/21/76	0:50:38	41:00	155:00	3:3	3	KURILE ISLANDS	221
848	5/21/76	4:32:19	41:00	163:00	3:6	3	UZBEK SSR	227
849	5/21/76	13:32:19	41:00	140:00	3:6	3	HONSHU, JAPAN	227
850	5/21/76	16:55:25	33:00	64:00	4:0	1	UZBEK SSR	339
851	5/21/76	18:08:50	30:00	64:00	3:9	2	UZBEK SSR	339
852	5/22/76	18:23:38	40:00	29:00	3:3	2	TURKEY	368
853	5/22/76	18:31:11	46:00	128:00	3:8	2	TURKISH INDIA	308
854	5/22/76	18:51:11	46:00	128:00	3:8	2	KURILE ISLANDS	221
855	5/23/76	3:53:50	39:00	30:00	3:6	3	TURKEY	366
856	5/23/76	9:26:52	38:00	21:00	4:0	3	IONIAN SEA	399
857	5/23/76	9:48:10	39:00	64:00	4:0	3	UZBEK SSR	339
858	5/23/76	10:58:48	39:00	54:00	4:1	2	NEC HONSHU, JAPAN	228
859	5/23/76	13:26:48	39:00	54:00	3:4	2	UZBEK SSR	339
860	5/24/76	6:10:46	39:00	64:00	3:8	2	UZBEK SSR	339
861	5/24/76	16:49:46	47:00	152:00	3:3	2	KURILE ISLANDS	221
862	5/24/76	18:56:27	41:00	162:00	4:3	2	UZBEK SSR	339
863	5/24/76	17:53:49	44:00	12:00	4:3	1	CENTRAL ITALY	381
864	5/25/76	4:48:49	42:00	94:00	4:6	1	EASTERN INDIA	311
865	5/25/76	7:29:11	43:00	148:00	3:5	1	KURILE ISLANDS	221
866	5/25/76	8:16:53	53:00	158:00	4:0	1	NEC KANCHATKA	218
867	5/25/76	10:53:16	53:00	158:00	4:0	2	NEC KANCHATKA	218
868	5/25/76	11:09:42	59:00	158:00	4:6	2	KURILE ISLANDS	221
869	5/25/76	11:17:42	52:00	160:00	3:9	2	NEC KANCHATKA	219
870	5/25/76	12:12:20	32:00	158:00	4:1	2	WESTERN IRAN	347
871	5/25/76	15:34:25	31:00	158:00	4:6	2	KURILE ISLANDS	221
872	5/25/76	18:43:29	31:00	83:00	4:3	3	TURKEY	366
873	5/25/76	18:43:29	31:00	83:00	4:3	3	TIBET	306

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RVNO	DATE	TIME	LAT.	LONG.	MB	2	LOCATION	SUBREG
875	5/27/76	6:44:15	40:0	58:0	3:7	2	UZBEK SSP	339
876	5/28/76	3:35:43	36:0	139:0	3:9	2	HONSHU, JAPAN	227
877	5/28/76	14:5:30	39:0	64:0	4:8	1	UZBEK SSR	339
878	5/28/76	23:2:19	43:0	30:0	4:4	2	TURKKEY	366
879	5/28/76	23:9:54	43:0	36:0	3:2	3	BLACK SEA	360
880	5/29/76	1:59:9	35:0	140:0	3:7	3	NEC HONSHU, JAPAN	228
881	5/29/76	3:45:33	39:0	30:0	3:9	3	TURKEY	368
882	5/29/76	8:28:22	39:0	114:0	3:7	3	NORTHEASTERN CHINA	658
883	5/29/76	10:21:13	38:0	21:0	3:9	3	IONIAN SEA	399
884	5/29/76	11:42:47	56:0	152:0	3:7	3	NEC PACHATKA	218
885	5/29/76	11:58:39	27:0	97:0	4:7	1	BURMA	296
886	5/29/76	12:33:36	24:0	96:0	5:2	1	BURMA-CHINA BORDER	297
887	5/29/76	12:35:55	28:0	97:0	3:9	2	INDIA-CHINA BORDER	313
888	5/29/76	12:59:51	25:0	97:0	3:4	3	BURMA-CHINA BORDER	297
889	5/29/76	13:55:51	28:0	96:0	3:0	2	INDIA-CHINA BORDER	313
890	5/29/76	14:1:16	24:0	99:0	6:2	1	BURMA-CHINA BORDER	297
891	5/29/76	14:11:32	28:0	96:0	3:3	3	INDIA-CHINA BORDER	313
892	5/29/76	14:28:37	27:0	97:0	4:7	2	INDIA-CHINA BORDER	313
893	5/29/76	14:32:10	26:0	98:0	4:4	2	BURMA-CHINA BORDER	297
894	5/29/76	14:53:10	26:0	98:0	4:4	2	BURMA-CHINA BORDER	297
895	5/29/76	15:3:15	29:0	95:0	3:4	3	INDIA-CHINA BORDER	313
896	5/29/76	15:26:40	20:0	30:0	3:3	3	TURKEY	366
897	5/29/76	16:5:40	24:0	98:0	3:3	3	BURMA-CHINA BORDER	297
898	5/29/76	17:9:13	27:0	97:0	3:3	3	BURMA	296
899	5/29/76	18:25:53	31:0	77:0	3:2	3	NORTHERN INDIA	308
900	5/29/76	19:37:25	28:0	96:0	5:2	2	INDIA-CHINA BORDER	313
901	5/29/76	21:57:13	41:0	20:0	3:3	3	GREECE-ALBANIA BOR.	392
902	5/29/76	22:5:19	35:0	24:0	3:3	2	CREE	370
903	5/29/76	23:12:29	37:0	140:0	3:3	3	HONSHU, JAPAN	318
904	5/29/76	23:31:29	25:0	99:0	3:3	3	YUNNAN, PROV. CHINA	318
905	5/30/76	0:40:12	28:0	99:0	3:9	3	BURMA-CHINA BORDER	297
906	5/30/76	3:15:19	39:0	54:0	3:4	3	UZBEK SSR	339
907	5/30/76	4:19:44	27:0	97:0	3:9	3	BURMA	396
908	5/30/76	4:53:52	43:0	47:0	3:7	2	ADRIATIC SEA	382
909	5/30/76	5:32:34	34:0	47:0	3:7	2	WESTERN IRAN	347
910	5/30/76	8:1:48	52:0	150:0	4:0	1	OPC KANCHATKA	219
911	5/30/76	13:11:47	53:0	157:0	4:3	1	KANCHATKA	217
912	5/30/76	13:46:21	41:0	21:0	3:3	2	GREECE-ALBANIA BOR.	392
913	5/30/76	16:27:11	41:0	21:0	3:3	2	GREECE-ALBANIA BOR.	392
914	5/30/76	17:31:18	34:0	48:0	3:3	3	WESTERN IRAN	347

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EVNO	DATE	TIME	LAT.	LONG.	HB	Q	LOCATION	SUBREG
915	5/30/76	19:43:39	25.0	97.0	3.7	3	EUROPA-CHINA BORDER	297
916	5/30/76	21:12:42	43.0	13.0	3.2	3	CENIRAL ITALY	381
917	5/30/76	22:16:20	41.0	77.0	3.8	3	KIRGIZ-SINKIANG BOR.	320
918	5/30/76	22:31:31	24.0	98.0	4.4	1	BURMA-CHINA BORDER	297
919	5/31/76	22:57:10	36.0	51.0	3.9	3	IRAN	348
920	5/31/76	5: 8:35	25.0	99.0	5.3	1	YUNNAN PROV. CHINA	318
921	5/31/76	8: 8:19	32.0	61.0	4.6	1	IRAN	348
922	5/31/76	13:17:35	28.0	154.0	5.1	2	KURILE ISLANDS	221
923	5/31/76	18:35:48	38.0	96.0	3.1	2	INDIA-CHINA BORDER	343
924	5/31/76	20:31:48	43.0	21.0	3.1	3	IONIAN SEA	399
925	5/31/76	20:51:38	43.0	150.0	3.6	3	KURILE ISLANDS REG.	222
926	6/ 1/76	1:37:41	27.0	29.0	2.8	3	TURKEY	366
927	6/ 1/76	1:59:12	28.0	97.0	3.9	3	TURKEY	296
928	6/ 1/76	10:59:16	27.0	94.0	4.0	1	BURMA	313
929	6/ 1/76	20:39:35	41.0	97.0	4.0	3	INDIA-CHINA BORDER	296
930	6/ 2/76	5:49:27	38.0	142.0	5.1	1	NEC HONSHU JAPAN	228
931	6/ 2/76	16:28:29	30.0	21.0	2.9	1	IONIAN SEA	399
932	6/ 2/76	18:55:49	49.0	54.0	1.1	3	IRAN	348
933	6/ 3/76	21:58:44	24.0	24.0	1.5	3	ROMANIA	358
934	6/ 3/76	48: 5:14	40.0	98.0	3.6	3	BURMA-CHINA BORDER	297
935	6/ 3/76	21:36:54	40.0	30.0	3.5	3	TURKEY	366
936	6/ 4/76	5: 7:48	39.0	48.0	3.9	3	WESTERN IRAN	347
937	6/ 4/76	5:26:59	38.0	142.0	3.0	3	NEC HONSHU JAPAN	228
938	6/ 4/76	5:48:50	41.0	21.0	3.6	3	IONIAN SEA	399
939	6/ 4/76	9:23:45	47.0	43.0	3.0	2	GREECE-ALBANIA BORDE	392
940	6/ 4/76	11:13:26	41.0	143.0	3.0	3	SW RUSSIA	357
941	6/ 5/76	10:46:29	28.0	95.0	3.0	2	NEC HONSHU JAPAN	228
942	6/ 5/76	14:21:38	41.0	21.0	3.7	2	INDIA-CHINA BORDER	343
943	6/ 5/76	20:30:38	41.0	21.0	3.7	2	GREECE-ALBANIA BOR	392
944	6/ 5/76	22:22:27	41.0	21.0	3.9	2	GREECE-ALBANIA BOR	392
945	6/ 6/76	13:51:44	35.0	154.0	4.1	2	KURILE IS	321
946	6/ 6/76	14: 1:13	38.0	140.0	5.0	1	NEC HONSHU JAPAN	228
947	6/ 6/76	14: 6:53	38.0	21.0	3.9	3	IONIAN SEA	399
948	6/ 6/76	14: 43:53	39.0	74.0	3.7	3	S SINKIANG PROV	321
949	6/ 7/76	5:31:41	38.0	21.0	2.7	3	IONIAN SEA	399
950	6/ 7/76	10:45:49	39.0	21.0	3.7	3	TURKISH SSR	340
951	6/ 8/76	11:59:30	27.0	94.0	3.3	2	EASTERN INDIA	317
952	6/ 8/76	18:37:33	38.0	21.0	3.6	2	IONIAN SEA	399

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EWID	DATE	TIME	LAT.	LONG.	NB	Q	LOCATION	SUBREG
955	6/ 8/76	22:31.31	33.0	89.0	4.0	3	TIBET	306
956	6/ 8/76	23:15.56	28.0	96.0	4.3	2	INDIA-CHINA BORDER	313
957	6/ 9/76	0:20.56	27.0	97.0	5.7	1	BUKHA	296
958	6/ 9/76	3: 2.48	50.0	81.0	5.3	1	EASTERN KAZAKH SSR	329
959	6/ 9/76	10: 2.42	40.0	29.0	4.4	2	TURKEY	366
960	6/ 9/76	17:41.14	31.0	96.0	4.7	3	TIPET	306
961	6/ 9/76	18:47.54	43.0	0	3.7	2	CENTRAL ITALY	381
962	6/ 9/76	20:58.27	40.0	13.0	3.6	3	UZBEK SSR	339
963	6/ 9/76	23:41.30	38.0	21.0	3.8	3	IONIAN SEA	339
964	6/10/76	0: 2.38	27.0	94.0	3.6	3	EASTERN INDIA	347
965	6/10/76	5:55.12	35.0	24.0	3.7	2	CRETE	370
966	6/11/76	0:52.44	40.0	76.0	4.6	1	TURKEY-SINKIANG BOR	366
967	6/11/76	5: 8.50	40.0	42.0	4.3	3	KIRGIZ-SINKIANG BOR	320
968	6/11/76	9: 7.54	47.0	30.0	3.3	3	SW RUSSIA	357
969	6/11/76	9:55.19	39.0	0	3.8	3	TURKEY	366
970	6/11/76	12: 5.31	39.0	30.0	4.7	3	TURKEY SEA	366
971	6/11/76	10:25.56	33.0	17.0	3.9	2	IONIAN SEA	399
972	6/11/76	18:27.49	33.0	21.0	3.3	2	ADRIATIC SEA	392
973	6/12/76	0:11.59	37.0	22.0	3.5	2	MEDITERRANEAN SEA	400
974	6/12/76	0:59.28	38.0	0	3.3	2	GREECE	354
975	6/12/76	2:41.16	35.0	24.0	3.8	2	CRETE	370
976	6/12/76	3:41.26	37.0	22.0	3.5	2	SOUTHERN GREECE	368
977	6/12/76	4:55.33	41.0	20.0	4.0	2	GREECE-ALBANIA BOR	392
978	6/12/76	10:20.24	40.0	19.0	3.3	2	ALBANIA	391
979	6/13/76	1:42.41	41.0	63.0	3.9	3	GREECE-ALBANIA BOR	392
980	6/13/76	1:25.47	29.0	85.0	3.8	3	UZBEK SSR	339
981	6/13/76	11:34.20	35.0	139.0	3.3	3	TIBET	306
982	6/13/76	16:54.17	27.0	157.0	3.8	2	HONSHU JAPAN	327
983	6/13/76	17:20.39	38.0	21.0	3.8	3	SOUTHERN IRAN	353
984	6/14/76	0:16.43	33.0	94.0	4.1	2	IONIAN SEA	399
985	6/14/76	6:52.19	40.0	28.0	4.1	3	TSINGHAI PROV CHINA	325
986	6/14/76	11:10.34	33.0	157.0	4.8	1	TURKEY	366
987	6/14/76	20:14.34	53.0	0	4.8	1	TIBET	217
988	6/15/76	0: 9.11	41.0	21.0	4.6	3	KAMCHATKA	391
989	6/15/76	0: 9.55	40.0	27.0	3.7	3	ALBANIA	366
990	6/15/76	6:21.57	37.0	95.0	3.4	2	TURKEY	306
991	6/15/76	12:46.25	35.0	24.0	3.4	2	BUKHA-INDIA BOR	370

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EWG	DATE	TIME	LAT.	LONG.	MB	Q	LOCATION	SUBREG
995	6/15/76	16:22:33	46.0	151.0	3.4	2	KURILE IS	221
996	6/15/76	18:11:19	40.0	129.0	3.4	1	TURKEY	366
997	6/15/76	20:33:59	35.0	130.0	4.9	1	REC HONSHU JAPAN	230
998	6/16/76	00:52:23	37.0	139.0	4.3	2	HONSHU JAPAN	227
999	6/16/76	04:20:13	36.0	77.0	3.7	2	EASTERN KASHMIR	302
1000	5/16/76	13:33:59	48.0	47.0	3.8	3	SW RUSSIA	357
1001	6/16/76	18:50:47	27.0	89.0	3.8	2	SIKKIM	311
1002	6/17/76	18:39:56	23.0	143.0	4.3	2	OFF E C HONSHU	229
1003	6/18/76	22:19:15	36.0	139.0	4.3	3	HONSHU JAPAN	227
1004	6/19/76	28:52:28	36.0	22.0	3.5	3	MEDITERRANEAN SEA	400
1005	6/19/76	14:25:33	49.0	29.0	3.6	3	TURKEY	366
1006	6/19/76	16:12:16	41.0	39.0	3.5	3	TURKEY	366
1007	6/19/76	16:17:23	39.0	64.0	4.4	3	TURKEY	340
1008	6/20/76	22:48:17	39.0	21.0	3.4	3	TURKEY	296
1009	6/20/76	04:51:41	41.0	21.0	3.4	3	GREECE	364
1010	6/20/76	15:28:32	28.0	95.0	4.0	2	GREECE-ALBANIA BOR	392
1011	6/20/76	15:30:56	27.0	97.0	4.0	3	INDIA-CHINA BOR	313
1012	6/20/76	23:33:56	41.0	63.0	4.8	1	BURMA	296
1013	6/20/76	01:28:17	41.0	77.0	3.8	2	IRAN	339
1014	6/21/76	09:11:27	39.0	48.0	3.7	2	KIRGIZ-SINKIANG BOR	320
1015	6/21/76	10:59:40	37.0	23.0	3.3	2	NW IRAN-USSR BORDER	344
1016	6/21/76	20:48:53	32.0	141.0	4.7	3	SOUTHERN GREECE	368
1017	6/21/76	10:41:39	45.0	36.0	3.2	3	HONSHU JAPAN	227
1018	7/8/76	11:20:38	35.0	24.0	4.5	3	IRAN	348
1019	7/8/76	15:26:40	27.0	51.0	4.0	3	CHINA REGION	221
1020	7/8/76	18:15:53	27.0	98.0	4.0	3	CHINA	370
1021	7/8/76	20:26:12	28.0	92.0	4.0	3	CHINA BOR REG	348
1022	8/5/76	10:26:12	28.0	143.0	4.0	2	KURILE IS	221
1023	8/5/76	18:26:00	28.0	143.0	4.0	3	NEAR E COAST HONSHU	313
1024	8/5/76	18:43:11	28.0	143.0	4.0	3	KURILE IS	221
1025	8/5/76	18:43:11	28.0	143.0	4.0	3	KURILE IS	221
1026	8/5/76	18:43:11	28.0	143.0	4.0	3	KURILE IS	221
1027	8/8/76	22:41:33	40.0	119.0	4.0	2	NE CHINA	658
1028	8/8/76	23:12:08	40.0	121.0	4.0	3	GREECE-ALBANIA BOR R	392
1029	8/8/76	23:36:27	40.0	121.0	4.0	3	NE CHINA	658
1030	8/9/76	23:12:27	40.0	121.0	4.0	3	IONIAN SEA	399
1031	8/9/76	23:20:32	40.0	121.0	4.0	3	KURILE IS	221

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FWNO	DATE	TIME	LAT.	LONG.	MB	Q	LOCATION	SUBREG
1253	8/9/76	35.41	39.0	54.0	3.4	2	UZRFX SSR	339
1254	8/9/76	5.46	33.0	145.0	3.4	3	OFF E COAST HONSHU	229
1255	8/9/76	8.50	33.0	97.0	4.4	3	TSINGHAI PROV	325
1256	8/9/76	10.32	20.0	78.0	3.7	2	NORTHEERN INDIA	308
1257	8/10/76	19.18	52.0	152.0	4.4	3	DEC KANCHATAKA	219
1258	8/10/76	22.38	42.0	118.0	3.4	3	NE CHINA	658
1259	8/10/76	23.32	30.0	119.0	3.2	3	NE CHINA	308
1260	8/11/76	5.12	38.0	21.0	3.6	3	NORIAN SEA	399
1261	8/11/76	6.57	34.0	91.0	3.8	3	TSINGHAI PROV	325
1262	8/11/76	9.00	46.0	153.0	3.6	2	KURILE IS REG	222
1263	8/12/76	16.17	38.0	13.0	3.1	3	SICILY	398
1264	8/12/76	18.11	52.0	40.0	3.3	3	SW RUSSIA	357
1265	8/12/76	23.28	43.0	97.0	6.0	1	BURMA-INDIA BOR REG	294
1266	8/12/76	0.63	28.0	140.0	5.0	2	HOKKAIDO JAPAN REG	224
1267	8/13/76	6.35	28.0	96.0	4.7	2	INDIA-CHINA BOR REG	313
1268	8/13/76	9.50	29.0	96.0	3.5	2	INDIA-CHINA BOR REG	313
1269	8/13/76	23.22	25.0	136.0	4.3	1	NEAR S COAST HONSHU	230
1270	8/13/76	23.56	20.0	121.0	3.9	2	INDIA-CHINA BOR R33	313
1271	8/14/76	1.23	35.0	62.0	3.0	3	NE CHINA	658
1272	8/14/76	4.30	35.0	96.0	4.4	1	INDIA-CHINA BOR REG	313
1273	8/14/76	7.10	40.0	121.0	3.5	3	CPETZ	370
1274	8/14/76	8.22	45.0	62.0	3.7	3	NE AFGHANISTAN	658
1275	8/14/76	8.48	45.0	62.0	3.7	3	SW RUSSIA	357
1276	8/14/76	0.26	31.0	53.0	3.3	3	IRAN	348
1277	8/14/76	10.16	43.0	29.0	3.4	3	BLACK SPA	360
1278	8/14/76	16.22	40.0	121.0	3.3	3	NE CHINA	658
1279	8/14/76	22.56	42.0	141.0	3.5	2	SOUTHERN IRAN	753
1280	8/15/76	5.18	21.0	94.0	3.7	2	HOKKAIDO JAPAN R2G	224
1281	8/15/76	10.37	49.0	119.0	3.4	3	BURMA	296
1282	8/15/76	10.32	38.0	110.0	3.8	3	NE CHINA	720
1283	8/15/76	10.53	38.0	110.0	3.8	3	NE CHINA	658
1284	8/15/76	12.42	36.0	130.0	3.6	3	HOESHU JAPAN	658
1285	8/15/76	22.30	39.0	113.0	3.8	2	NE CHINA	227
1286	8/15/76	23.11	39.0	152.0	3.2	3	KURILE IS	658
1287	8/16/76	4.11	39.0	48.0	3.2	3	NE IRAN	345

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EVNO	DATE	TIME	LAT.	LONG.	HE	Q	LOCATION	SUBREG
1292	8/16/76	7:25:32	36.0	79.0	3.7	2	KASHMIR-SINKIANG BOR	324
1293	8/16/76	8:42:51	35.0	24.0	3.5	3	CHINA	370
1295	8/16/76	9:38:28	46.0	159.0	2.9	1	SH RUSSIA	357
1296	8/16/76	12:29:58	52.0	100.0	5.2	1	NEC KANCHATKA	218
					6.2		KANSU PROV CHINA	322
1297	8/16/76	18:56:25	31.0	105.0	3.8	2	SZECHEWAN CHINA	307
1298	8/16/76	14:57:00	35.0	103.0	3.5	1	TSINGHAI PROV CHINA	325
1300	8/16/76	15:06:54	33.0	105.0	4.4	1	SZECHEWAN PROV CHINA	307
1301	8/16/76	18:15:54	35.0	103.0	4.0	2	TSINGHAI PROV CHINA	307
1302	8/16/76	18:54:35	33.0	105.0	3.7	3	SZECHEWAN PROV CHINA	307
1304	8/16/76	20:26:50	40.0	104.0	3.4	3	SZECHEWAN PROV CHINA	307
1305	8/16/76	21:23:34	46.0	117.0	3.4	2	NE CHINA	658
1306	8/16/76	21:30:32	31.0	81.0	3.3	2	NORTHEPN INDIA	308
					3.6		SZECHEWAN PROV CHINA	307
1307	8/16/76	22:06:38	33.0	105.0	3.1	2	SZECHEWAN PROV CHINA	307
1308	8/16/76	22:41:26	41.0	139.0	4.8	1	TURKEY	366
1309	8/17/76	2:03:33	43.0	149.0	3.4	2	KUWAIT ISLANDS	222
1311	8/17/76	2:27:43	35.0	103.0	3.4	3	UZBEK SSR	339
1312	8/17/76	3:48:27	38.0	100.0	3.6	2	TSINGHAI PROV CHINA	325
1313	8/17/76	5:19:54	35.0	103.0	3.4	2	TSINGHAI PROV CHINA	325
1314	8/17/76	17:19:31	34.0	103.0	3.9	1	HONSHU JAPAN	227
1315	8/17/76	22:17:24	39.0	104.0	3.6	3	KANSU PROV CHINA	322
1316	8/18/76	0:58:24	39.0	24.0	3.6	2	ARABIAN SEA	36
1317	8/18/76	2:25:37	38.0	21.0	7.7	3	IONIAN SEA	399
1318	8/18/76	2:30:53	39.0	94.0	3.3	2	INDIA-CHINA BOR RES	313
1319	8/18/76	17:06:11	35.0	27.0	3.0	2	CHINA	370
1320	8/19/76	17:52:29	33.0	158.0	3.2	1	NEC KANCHATKA	218
1321	8/19/76	12:49:45	33.0	105.0	3.5	2	SZECHEWAN PROV CHINA	307
1322	8/19/76	19:20:16	41.0	21.0	4.6	3	GREECE	364
1323	8/20/76	15:09:43	40.0	141.0	3.0	2	HOKKAIDO, JAPAN RES.	224
1324	8/20/76	19:04:25	36.0	74.0	3.3	2	TURKEY	366
1325	8/20/76	21:05:23	37.0	77.0	3.4	3	NE KASHMIR	720
1326	8/20/76	22:18:26	39.0	82.0	3.4	2	KASHMIR-SINKIANG BOR	324
1327	8/20/76	23:43:36	43.0	148.0	3.2	3	S SINKIANG PROV	321
1328	8/21/76	20:09:20	26.0	195.0	4.1	2	OFF COAST HOKKAIDO	225
1329	8/21/76	21:49:54	32.0	104.0	3.4	1	BUENIA-INDIA BOR RES	294
1330	8/21/76				6.1		NE CHINA	658
1331	8/21/76						SZECHEWAN PROV CHINA	307

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EVNO	DATE	TIME	LAT.	LONG.	MB	Q	LOCATION	SUBREG
1332	8/21/76	22:40:50	33.0	105.0	3.7	3	SZECHWAN PROV CHINA	307
1333	8/22/76	3:5:15	41.0	39.0	3.6	2	TURKEY	366
1334	8/22/76	8:48:20	43.0	17.0	3.4	2	ADRIATIC SEA	382
1335	8/22/76	9:42:09	40.0	23.0	3.6	2	GREECE	364
1336	8/22/76	13:19:55	33.0	105.0	4.2	2	SZECHWAN PROV CHINA	307
1337	8/22/76	13:28:56	40.0	29.0	4.8	2	TURKEY	366
1338	8/22/76	14:46:19	39.0	14.0	3.2	2	SICILY	398
1339	8/22/76	16:6:15	41.0	21.0	3.6	2	GREECE-ALBANIA BOR	392
1340	8/22/76	21:55:15	45.0	34.0	3.9	2	CHINA REG	361
1341	8/23/76	1:52:19	27.0	96.0	3.3	2	BURMA-INDIA BOR REG	294
1342	8/23/76	3:15:40	41.0	23.0	4.3	2	ALBANIA	391
1343	8/23/76	3:31:22	34.0	103.0	6.3	2	KANSU PROV CHINA	322
1344	8/23/76	4:31:11	33.0	105.0	3.0	2	SZECHWAN PROV CHINA	307
1345	8/23/76	5:34:11	35.0	27.0	3.8	2	CRETE	370
1346	8/23/76	6:43:30	33.0	105.0	3.3	2	SZECHWAN PROV CHINA	307
1347	8/23/76	8:58:37	35.0	103.0	4.0	2	KANSU PROV. CHINA	322
1348	8/23/76	10:17:16	45.0	149.0	3.9	2	NEAR E COAST HONSHU	228
1349	8/23/76	12:12:37	46.0	152.0	3.4	2	KORILLES IS	228
1350	8/23/76	17:15:37	36.0	119.0	4.1	2	NE CHINA	258
1351	8/23/76	20:35:11	36.0	175.0	3.4	2	NW KASHMIR	720
1352	8/23/76	21:2:28	35.0	103.0	4.3	2	TSINGHAI PROV CHINA	325
1353	8/24/76	0:52:47	29.0	149.0	3.8	2	WESTERN IRAN	357
1354	8/24/76	4:52:45	29.0	102.0	3.3	2	SZECHWAN PROV CHINA	307
1355	8/24/76	7:26:46	36.0	102.0	4.3	2	NEAR COAST HONSHU	228
1356	8/24/76	8:0:6	38.0	22.0	3.3	2	MEDITERRANEAN SEA	400
1357	8/24/76	16:10:36	41.0	21.0	3.0	2	IONIAN SEA	399
1358	8/24/76	23:26:19	42.0	21.0	3.1	2	GREECE-ALBANIA BOR	392
1359	8/25/76	1:56:38	35.0	124.0	3.3	2	NE CHINA	358
1360	8/25/76	17:31:38	37.0	119.0	3.2	2	CRETE	370
1361	8/26/76	12:6:31	42.0	142.0	4.7	2	NE CHINA	358
1362	8/27/76	2:32:14	45.0	149.0	4.3	2	HOKKAIDO JAPAN REG	224
1363	8/27/76	16:53:31	38.0	154.0	3.5	2	KORILLES IS	221
1364	8/27/76	22:45:43	35.0	27.0	3.4	2	TPAN	348
1365	8/27/76	23:57:37	39.0	64.0	3.7	2	SOUTHERN SINKIANG	321
1366	8/28/76	2:56:43	49.0	81.0	6.0	2	CRETE	370
1367	8/28/76	10:33:53	36.0	101.0	3.9	2	UZBEK SSR	339
1368	8/28/76	16:32:48	45.0	117.0	4.1	2	EASTERN KAZAKH SSR	329
1369	8/28/76	16:32:48	36.0	101.0	3.9	2	NE CHINA	358
1370	8/28/76	16:32:48	45.0	117.0	4.1	2	WE CHINA	325
1371	8/28/76	16:32:48	45.0	117.0	4.1	2	WE CHINA	325

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SYNO	DATE	TIME	LAT.	LONG.	HB	Q	LOCATION	SUBRBG
1372	8/28/76	18:59:55	35.0	103.0	3.8	3	TSINGHAI PROV CHINA	325
1373	8/28/76	23:14:12	38.0	91.0	3.2	3	S SIKHANG PROV	327
1374	8/29/76	1:14:56	36.0	143.0	3.7	3	EASTERN INDIA	317
1375	8/29/76	1:51:25	36.0	143.0	3.7	3	HOKKAIDO JAPAN REG.	224
1376	8/29/76	16:49:52	36.0	140.0	3.7	3	NEAR S COAST HONSHU	230
1377	8/29/76	19:31:7	43.0	20.0	3.0	2	YUGOSLAVIA	383
1378	8/29/76	20:12:7	31.0	47.0	4.4	2	IRAN-IRAQ BOR REG	346
1379	8/29/76	23:39:18	44.0	182.0	4.2	2	HOKKAIDO JAP REG	224
1380	8/30/76	0:08:18	20.0	96.0	3.2	2	BURMA	296
1381	8/30/76	15:49:47	44.0	147.0	4.3	2	KURILE IS	227
1382	8/30/76	17:41:16	42.0	143.0	4.3	2	HOKKAIDO JAP	228
1383	8/31/76	13:25:55	37.0	123.0	4.9	2	NE CHINA	258
1384	8/31/76	11:20:23	43.0	123.0	3.3	2	RULGARIA	359
1385	9/1/76	11:27:14	35.0	103.0	4.6	2	TSINGHAI PROV. CHINA	325
1386	9/1/76	11:15:10	39.0	164.0	3.7	3	TURKISH SSR	340
1387	9/2/76	19:54:6	32.0	49.0	4.0	2	WESTERN IRAN	347
1388	9/2/76	21:37:39	38.0	21.0	3.4	1	LOMIAN SEA	302
1389	9/3/76	9:57:36	29.0	99.0	4.9	1	SZECHUAN PROV. CHINA	307
1390	9/3/76	0:14:32	41.0	122.0	4.3	2	NORTHERN CHINA	306
1391	9/5/76	9:54:32	36.0	180.0	3.6	3	KASHMIR-TIBET BORDER	304
1392	9/5/76	10:42:16	44.0	142.0	5.0	1	HOKKAIDO JAPAN REG	248
1393	9/5/76	16:43:13	31.0	158.0	3.7	1	IRAN	221
1394	9/5/76	22:7:39	41.0	64.0	4.3	2	KURILE ISLANDS	366
1395	9/6/76	11:2:44	46.0	68.0	3.9	3	TURKEY	342
1396	9/6/76	16:4:38	37.0	51.0	4.1	2	TURKISH-AFGHANISTAN	357
1397	9/6/76	17:1:38	45.0	130.0	4.1	2	SOUTHWESTERN RUSSIA	348
1398	9/6/76	3:27:57	39.0	163.0	4.3	2	IRAN	658
1399	9/7/76	6:3:21	39.0	115.0	4.1	2	NORTHWESTERN CHINA	658
1400	9/7/76	9:20:27	43.0	123.0	3.3	2	IRAN	229
1401	9/7/76	19:37:51	49.0	156.0	3.5	2	NORTHEASTERN CHINA	658
1402	9/7/76	17:59:47	38.0	78.0	3.5	2	KURILE ISLANDS REG	222
1403	9/8/76	20:13:4	32.0	79.0	3.0	1	SOUTHERN SIKHANG PR	321
1404	9/8/76	0:43:1	41.0	21.0	3.5	3	TIBET-INDIA BORDER	305
1405	9/12/76	7:29:47	41.0	133.0	3.1	3	GREECE-ALBANIA BORD	392
1406	9/13/76	4:15:38	40.0	120.0	3.3	3	NORTHERN CHINA	323
1407	9/13/76	5:45:53	44.0	112.0	3.3	3	CRETE	370
1408	9/13/76	19:41:53	44.0	112.0	3.3	3	NORTHEASTERN CHINA	658
1409	9/13/76	19:41:53	44.0	112.0	3.3	3	CENTRAL ITALY	381

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EVNO	DATE	TIME	LAT.	LONG.	HB	Q	LOCATION	SUBREG
1412	9/13/76	19:57:8	33.0	105.0	3.7	2	SZECHWAN PROV. CHINA	307
1413	9/14/76	16:43:19	30.0	89.0	5.2	1	TIBET	306
1414	9/14/76	10:52:19	41.0	81.0	3.7	3	SOUTHERN SINKIANG	321
1415	9/14/76	15:38:31	37.0	96.0	4.3	3	TSINGHAI PROV. CHINA	325
1416	9/14/76	18:23:43	27.0	86.0	3.6	3	NEPAL	310
1417	9/14/76	23:41:35	29.0	53.0	4.4	1	SOUTHERN IRAN	353
1418	9/15/76	8:20:16	39.0	143.0	4.4	1	NEC HONSHU JAPAN	228
1419	9/15/76	9:57:34	43.0	117.0	3.2	3	ADRIATIC SEA	382
1420	9/15/76	18:52:58	31.0	105.0	3.7	2	SZECHWAN PROV. CHINA	307
1421	9/15/76	20:59:10	37.0	139.0	4.1	2	HONSHU JAPAN	227
1422	9/16/76	1:45:7	32.0	49.0	3.6	3	WESTERN IRAN	347
1423	9/17/76	11:11:19	34.0	159.0	4.0	2	HOKKAIDO JAPAN REG	224
1424	9/17/76	23:17:24	33.0	59.0	4.5	3	IRAN	348
1425	9/18/76	11:48:7	42.0	51.0	3.7	2	CASPIAN SEA	338
1426	9/18/76	19:14:59	40.0	120.0	4.7	3	NORTHEASTERN CHINA	658
1427	9/19/76	0:48:11	20.0	93.0	3.9	2	BURMA	296
1428	9/19/76	2:11:57	42.2	146.0	4.1	0	HOKKAIDO, JAPAN REG.	224
1514	11/1/76	4:56:2	56.2	143.0	5.1	0	HOKKAIDO, JAPAN REG.	227
1515	11/1/76	14:29:30	25.7	111.6	5.5	0	LAKE BAIKAL REG.	327
1516	11/3/76	3:59:52	6.0	125.2	5.5	0	NORTHEAST OF TAIWAN	245
1517	11/3/76	5:41:7	25.0	143.7	5.8	0	ROC HONSHU, JAPAN	329
1518	11/4/76	11:20:7	61.5	144.2	5.1	0	YUNNAN PROV. CHINA	343
1519	11/5/76	13:59:57	44.3	144.7	5.3	0	HOKKAIDO, JAPAN REG	224
1520	11/5/76	6:30:0	5.3	148.5	5.0	0	CENTRAL SIBERIA	726
1521	11/6/76	4:43:54	26.5	96.4	5.0	0	KURILE ISLANDS	221
1522	11/6/76	7:57:25	35.0	138.9	5.0	0	BURMA	296
1523	11/6/76	15:0:52	50.6	156.1	5.1	0	HONSHU, JAPAN	227
1524	11/6/76	18:50:12	27.4	101.1	5.1	0	KURILE ISLANDS	227
1527	11/7/76	4:0:50	33.7	59.2	5.0	0	SZECHWAN, CHINA	307
1528	11/7/76	8:16:0	27.5	101.1	4.9	0	SZECHWAN, CHINA	307
1529	11/8/76	0:0:53	44.7	148.1	4.9	0	KURILE ISLANDS	221
1530	11/8/76	6:48:27	38.1	177.4	5.0	0	SOUTHERN SINKIANG	321
1531	11/8/76	8:19:27	35.7	142.2	5.0	0	NEC HONSHU, JAPAN	228
1532	11/8/76	9:7:57	47.4	145.9	5.0	0	SEA OF OKHOTSK	663
1533	11/8/76	23:27:42	47.8	146.3	5.0	0	NW OF KURILE IS. CHINA	220
1534	11/9/76	22:49:4	36.4	101.1	5.3	0	SZECHWAN PROV. CHINA	307
1535	11/9/76	12:54:8	36.4	70.3	4.7	0	TADZHIK-SINKIANG BOR	719
1536	11/9/76						HINDU KUSH REGION	718

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RVNO	DATE	TIME	LAT.	LONG.	HB	Q	LOCATION	SUBREG
1537	11/12/76	13:13:41	39.9	116.8	4.7	0	NORTHEASTERN CHINA	658
1538	11/13/76	10:12:33	28.2	157.4	5.0	0	SOUTHERN IRAN	353
1539	11/15/76	3:14:46	49.3	155.1	4.9	0	KURILE ISLANDS	221
1540	11/15/76	3:14:50	49.3	155.6	4.8	0	KURILE ISLANDS	221
1541	11/15/76	7:6:34	38.6	130.8	4.8	0	KYUSHU, JAPAN	235
1542	11/15/76	8:3:23	33.2	47.9	5.4	0	WESTERN IRAN	347
1543	11/15/76	13:53:37	39.3	117.7	6.0	0	NORTHEASTERN CHINA	658
1544	11/17/76	15:23:24	51.3	116.3	5.5	0	KANCHATAKA	217
1545	11/17/76	17:23:24	36.5	111.7	5.4	0	AFGHANISTAN-USSR BOR	217
1546	11/19/76	18:11:32	24.4	122.7	4.6	0	TAIWAN REGION	243
1547	11/21/76	9:23:7	29.9	139.4	4.6	0	S. OF HONSHU, JAPAN	211
1548	11/22/76	13:6:2	51.0	147.8	5.5	0	S. OF HONSHU, JAPAN	229
1549	11/23/76	15:3:36	51.0	178.3	5.5	0	EASTERN KAZAKH SSR	229
1550	11/23/76	16:46:15	52.0	159.7	5.5	0	OEC KANCHATAKA	219
1551	11/24/76	16:9:15	52.0	160.7	5.5	0	OEC KANCHATAKA	219
1552	12/1/76	9:1:47	39.4	73.1	8.9	0	TADZHIK-SINKIANG BOR	719
1553	12/1/76	11:59:35	27.0	54.9	4.7	0	SOUTHERN IRAN	353
1554	12/2/76	0:42:58	39.7	117.5	4.9	0	NORTHEASTERN CHINA	658
1555	12/3/76	1:19:26	31.1	139.3	4.6	0	S. OF HONSHU, JAPAN	211
1556	12/3/76	13:57:26	31.1	139.3	4.6	0	S. OF HONSHU, JAPAN	211
1557	12/3/76	22:35:49	33.0	47.9	4.3	0	IRAN-IRAQ BORDER	346
1558	12/7/76	4:56:57	49.9	73.0	5.5	0	EASTERN KAZAKH SSR	329
1559	12/7/76	9:36:47	33.1	137.0	5.0	0	NEAR S. COAST HONSHU	230
1560	12/7/76	9:36:47	33.1	135.6	4.9	0	SOUTHERN HONSHU	232
1561	12/11/76	4:9:26	33.7	46.5	5.0	0	IRAN-IRAQ BORDER	346
1562	12/11/76	5:36:57	41.9	142.5	4.9	0	HOKKAIDO, JAPAN	224
1563	12/11/76	8:39:9	43.8	160.5	5.0	0	NEC KANCHATAKA	218
1564	12/12/76	7:54:20	39.0	44.2	4.8	0	TURKEY-IRAN BORDER	343
1565	12/14/76	19:35:16	30.0	132.4	5.3	0	S. OF SHIKOKU, JAPAN	217
1566	12/14/76	20:22:21	35.1	159.0	6.0	0	KANCHATAKA	217
1567	12/19/76	11:43:45	50.7	159.4	4.8	0	KURILE ISLANDS REG.	228
1568	12/20/76	18:30:10	51.2	158.0	4.9	0	NEC KANCHATAKA	218
1569	11/16/76	23:18:43	28.5	157.1	4.8	0	SOUTHERN IRAN	353
1570	11/17/76	11:57:43	27.5	101.1	5.1	0	SZACHWAN PROV. CHINA	307
1571	11/17/76	11:7:57	33.2	48.0	5.5	0	WESTERN IRAN	347
1572	11/9/76	17:59:54	33.8	59.2	5.1	0	IRAN	348
1573	11/10/76	19:45:58	39.4	75.0	4.6	0	S. SINKIANG PROV. BOP	321
1574	11/11/76	20:20:8	39.4	73.3	5.5	0	TADZHIK-SINKIANG	219
1575	11/12/76	5:6:2	44.8	149.3	5.2	0	KURILE ISLANDS	211
1576	11/12/76	21:27:14	27.6	101.2	4.4	0	SZACHWAN PROV. CHINA	307

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RVNO	DATE	TIME	LAT.	LONG.	NB	Q	LOCATION	SUBREG
1577	11/10/76	17:10:39	37.1	141.5	5.1	0	EC HONSHU, JAPAN	228
1578	11/15/76	12:55:12	42.5	142.4	4.8	0	KURILE ISLANDS	716
1579	11/15/76	14:14:18	45.2	148.4	5.1	0	SZECHWAN PROV. CHINA	221
1580	11/16/76	11:10:21	27.4	131.1	5.3	0	KURILE ISLANDS	307
1591	11/17/76	15:33:35	51.0	156.2	5.5	0	KURILE ISLANDS	221
1582	11/19/76	15:14:1	35.1	141.7	5.2	0	EC HONSHU, JAPAN	228
1583	11/20/76	4:19:36	36.3	69.2	4.8	0	HINDU KUSH REGION	718
1584	11/22/76	2:32:20	23.9	122.4	4.8	0	TAIWAN REGION	243
1585	11/24/76	12:22:19	39.1	44.0	6.1	0	NW IRAN-USSR BOR.	344
1586	11/24/76	12:30:41	39.1	43.9	5.0	0	TURKEY	366
1587	11/24/76	12:36:46	39.2	44.3	5.8	0	NW IRAN-USSR BOR.	344
1588	11/24/76	13:18:7	39.1	43.7	4.8	0	TURKEY	366
1589	11/24/76	15:11:4	39.2	43.7	4.9	0	TURKEY	344
1590	11/24/76	15:11:5	39.2	43.7	4.9	0	NW IRAN-USSR BOR.	344
1591	11/24/76	20:46:6	39.1	44.0	4.8	0	NW IRAN-USSR BOR.	344
1592	11/27/76	6:17:41	36.8	138.2	4.8	0	HONSHU, JAPAN	227
1593	11/27/76	15:12:10	36.2	71.4	4.0	0	AFGHANISTAN-USSR BOR	717
1594	11/27/76	21:43:12	36.5	71.0	4.1	0	AFGHANISTAN-USSR BOR	717
1595	11/28/76	20:39:39	41.1	140.7	5.2	0	HOKKAI DOO, JAPAN REG.	224
1596	11/28/76	20:39:39	40.2	63.8	4.4	0	UZBEK SSR	339
1597	11/29/76	8:16:29	42.0	142.5	5.1	0	HOKKAI DOO, JAPAN REG.	224
1598	11/29/76	19:44:39	51.2	159.5	4.6	0	EC KANCHATAKA	219
1599	12/1/76	9:11:47	39.5	73.1	4.9	0	TADZHIK-SINKIANG BOR	719
1600	12/1/76	11:59:35	27.0	54.9	4.7	0	SOUTHERN IRAN	353
1601	12/2/76	10:42:58	29.7	117.5	4.9	0	NORTHEASTERN CHINA	658
1602	12/2/76	11:19:29	31.0	139.5	5.6	0	S. OF HONSHU, JAPAN	211
1603	12/2/76	17:19:44	39.7	139.3	4.9	0	S. OF HONSHU, JAPAN	211
1604	12/2/76	5:16:25	39.1	139.1	4.7	0	S. SINKIANG PROV. JAPAN	321
1605	12/3/76	20:34:30	39.1	44.1	4.0	0	S. OF HONSHU, JAPAN	344
1606	12/4/76	4:10:33	39.3	43.6	4.8	0	TURKEY	366
1607	12/4/76	21:12:54	39.6	73.4	4.8	0	TADZHIK-SINKIANG BOR	719
1608	12/5/76	19:14:54	39.0	43.4	4.2	0	TURKEY	366
1609	12/5/76	3:58:4	38.9	44.4	4.4	0	NW IRAN-USSR BOR.	344
1610	12/6/76	4:06:5	38.9	44.4	4.4	0	TURKEY-IRAN BORDER	343
1611	12/6/76	16:13:12	24.2	94.6	4.7	0	BURMA-INDIA BORDER	294
1612	12/8/76	17:40:32	24.5	99.0	4.5	0	YUNNAN PROV. CHINA	318
1613	12/9/76	15:37:41	51.4	147.8	4.2	0	KURILE ISLANDS	221
1614	12/9/76	15:59:21	27.6	159.4	4.6	0	EC KANCHATAKA	219
1615	12/9/76	20:2:26	27.6	156.2	4.6	0	SOUTHERN IRAN	353

TABLE A-1
DATA BASE
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EVNO	DATE	TIME	LAT.	LONG.	MS	Q	LOCATION	SUBREG
1617	12/11/76	17:56:49	38.1	73.8	4.9	0	TADZHIK-SINKIANG ROR	719
1618	12/11/76	10:35:46	35.1	153.4	4.8	0	KURILE ISLANDS	221
1620	12/12/76	10:30:30	39.7	74.1	5.1	0	S. SINKIANG PROV.	321
1621	12/13/76	2:55:59	35.7	180.7	5.4	0	EC PONSU JAPAN	322A
1622	12/13/76	6:36:54	27.4	101.1	5.4	0	SZEPHIAN PROV. CHINA	307
1623	12/13/76	7:23:47	27.3	101.1	5.4	0	SZEPHIAN PROV. CHINA	307
1624	12/15/76	23:14:32	31.1	142.2	5.0	0	S. OF HONSHU, JAPAN	307
1625	12/17/76	10:27:26	38.6	85.0	5.0	0	PASIFERN KAZAKH SSR	321
1626	12/18/76	13:22:11	32.3	93.9	5.8	0	SINGHAT PROV. CHINA	323
1627	12/19/76	3:05:56	35.3	142.2	5.7	0	EC HONSHU, JAPAN	228
1628	12/19/76	0:05:30	37.4	72.3	4.7	0	TADZHIK SSP	715
1629	12/19/76	16:37:53	46.6	151.6	5.3	0	KURILE ISLANDS	221
1630	12/19/76	15:22:25	6.0	142.2	4.4	0	HOKKAIDO, JAPAN	224

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